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The Development of a Design for Service Strategy

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THE DEVELOPMENT OF A DESIGN FOR SERVICE STRATEGY

BY

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ABSTRACT

When considering the design of a new product, the aspect of serviceability and reliability are becoming major concerns for the product manufacturer. Moreover, when consumers consider purchasing a new product they are no longer just concerned with the initial purchase cost; they are becoming increasingly concerned with the "total" cost of ownership, part of which is the cost of service.

Although many of the operations found in service tasks resemble those encountered during initial assembly operations, there are many distinct differences. By utilizing design for assembly techniques the simplification of product assembly is assured but it does not guarantee that the product can be easily disassembled and serviced. In fact some of the "ideal" DFA conditions may negatively impact on the ease of serviceability of the product.

Previous research conducted in Design for Service, in the department of Industrial and Manufacturing Engineering, has led to the development of time databases for specific operations, yet the research has not dealt with several other key issues, like the effect of operator position on the service time. The present research project has focused on determining how a product will be serviced and on determining which service procedures should be examined for improvements in efficiency. The importance procedure developed, will allow the design team to focus efforts to improve the service tasks which have been identified as important based on their failure rate and consequence of failure.

PREFACE

This thesis presents the work completed in the development of a strategy for designing products for ease of service. The strategy deals with determining a service structure organization as well as providing a method to rank service procedures based on their importance. The thesis is written in manuscript format. Chapter 1 is an introduction describing the goals of the research and the importance of the work. Chapter 2 briefly reviews some terminology common to serviceability, maintainability and reliability. Chapter 3 contains the procedures to determine which tasks are the most important. It also contains a method to classify each service procedure, whether it be corrective or preventive, and to determine at what level the product should be repaired. Chapter 4 discusses some additions to the DFS database and a relationship between service task efficiency and service task importance using a ranking procedure. Chapter 5 contains case studies to demonstrate how the procedures developed can be applied to actual products. Chapter 6 summarizes the work completed for this thesis and suggests related areas for future work.

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NOMENCLATURE

A = The average cost or time of production

A_I = Inherent availability

A_O = Operational availability

a = The cost or time of the first unit

b = The reduction exponent derived from $\frac{\log r}{\log f}$ (will always be negative)

C_d = Value of discard items ($) (items such as seals that must be replaced simply because

C_{dp} = The expected cost of damaged parts

C_f = The cost of failure source(s) ($)

C_p = The cost of a replacement system ($)

C_r = Consequence Rank

C_{rc} = The cost to return the system to operating conditions ($)

C_s = Value of service item ($)

C_{sub} = The cost of replaced assembly/subassembly ($)

C_t = Cost of special tools or equipment required ($)

F_r = Frequency Rank

f = The factor increase in output (usually in terms of 2)

$f_1, f_2, \ldots, f_n$ = The failure frequencies for items 1, 2, •••, n respectively

I = Individual unit time or cost

I_f = Failure source replacement index

I_r = Importance rank

I_s = Assembly/subassembly replacement index

L = Labor rate ($/sec)

MDT = Mean downtime

MTBF = Mean time between failures

MTTF = Mean time to failure

MTTR = Mean time to repair

N_m = The theoretical minimum number of parts that can be justified for removal in the

P_m = The associated position modifier

R_A = Reliability of subsystem A

R_B = Reliability of subsystem B

R_C = Reliability of subsystem C

R_S = Reliability of the system

r = The rate of improvement represented by a decreasing percentage of the original time service task

T = Total time or cost

T_{Acq} = Item acquisition time (sec)

T_f = The time to replace failure source (seconds)

$T_{Ins.Snap}$ = Item insertion time for snap fit items (sec)

$T_{Ins.Un}$ = Item insertion time for unsecured items (sec)

T_o = Time to perform 1 operation repetition with penalties

$T_{Rem.Snap}$ = Item removal time for snap fits (sec)

$T_{Rem.Un}$ = Unsecured item removal time (sec)

$T_{Setaside}$ = Item set-aside time (sec)

T_s = Estimated time to perform service task (sec)

T_{sub} = the time to replace assembly/subassembly (seconds)

T_t = Total time for 1 repetition of the operation

they have been disassembled)

t_{min} = Ideal service time (sec)

x = The number of units to be produced

$\eta_1, \eta_2, \cdots, \eta_n$ = Time based efficiency index values for tasks 1, 2, •••, n respectively

η_{cost} = DFS cost based service efficiency index

η_{time} = DFS time based service efficiency index

λ = the failure rate of the item

λ_s = Failure rate of the system

Chapter 1: Introduction

When considering the design of a new product, the aspect of serviceability and reliability are becoming major concerns for the product manufacturer. Moreover, when consumers consider purchasing a new product they are no longer just concerned with the initial purchase cost; they are becoming increasingly concerned with the "total" cost of ownership, part of which is the cost of service.

With recent increased consumer interest in "green" products, extending product life by reducing the cost of repair becomes a major marketing advantage. Currently it is often cheaper to dispose of products such as home appliances and electronic equipment, than to restore them to the proper operating conditions. By reducing the cost of service, the useful life of many products can be extended, thereby reducing the amount of these products that are placed in landfills each year.

Although many of the operations found in service tasks resemble those encountered during initial assembly operations, there are many distinct differences. By utilizing design for assembly techniques the simplification of product assembly is assured but it does not guarantee that the product can be easily disassembled and serviced. In fact some of the "ideal" DFA conditions may negatively impact on the ease of serviceability of the product. When a product is originally assembled, often fixtures and automatic tools are available to aide in the assembly process, this is often not the case when a product is sent in for service. Disassembly of a product is seldom considered when the initial design work is being done, but efficient disassembly of a product will increase its serviceability while simultaneously increasing the recyclability of that product.

The task of optimizing a product for ease of service is fundamentally different from that of optimizing a design for ease of initial assembly. For initial assembly the goal in design is the simply stated one of minimizing assembly time or cost. For service, on the other hand, there are inevitable conflicts between the different service tasks which must be carried out on a particular product. The perfect design for service would have all of the items to be replaced in service, and all of the service operations to be performed, immediately accessible on the outer surface of the product. Clearly, this is not generally possible and so decisions have to be made about which items are to be most easily accessible. Even when this decision has been made, the ease with which the service tasks should be performed is still a matter for deliberation. At one extreme the product user should be alerted that a problem has occurred and corrective action should be possible without documentation or tools and with the absolute minimum of disassembly operations. At the other extreme, the efficiency of initial manufacture should not be compromised in any way to allow easier disassembly for service. For example, spot welding may be a preferred fastening technique even though spot welds may have to be drilled out occasionally to allow service tasks to be performed. This research will detail a procedure used to determine which service tasks are the most important by ranking them in accordance to their failure frequency and failure consequence. Also, this procedure may be used to determine if the service procedure needs to be improved upon or if no improvement to the current design is necessary.

1.1 Background and Related Research

To date research in DFS at the University of Rhode Island has mainly focused on the development of time databases that are used to predict service times. The current DFS analyses can be used to estimate the cost of servicing an item that has either stopped functioning correctly, requiring corrective service, or is being replaced as part of routine maintenance or preventive service. The times represented in the databases were obtained from videotapes, and time standard systems such as MOST [1,2,3]. Product case studies were used for validation of the times given in the databases. These databases provide a fairly accurate method for estimating the cost of servicing a product in the early design stages.

Also, a great deal of literature is published on the topic of maintainability and reliability in product design. [4,5,6,7,8,9] Most of the information found is derived from military standards used primarily by the aerospace industry. Fault Tree Analysis and Failure Modes and Effects Analysis were developed to aide in improving the reliability of a product by identifying weak areas in the products design. The importance of predicting maintenance frequencies and the associated costs of service seemed to arise around World War II.

1.2 Project Description and Objectives

There are three segments of this project. Initially effort was focused on developing a system with which a service engineer could set up the service organization structure for a product. With this system the designer could determine whether a task is preventive or corrective in nature. They will also be able to determine which tasks should be examined from a serviceability standpoint based on the failure frequency and the consequence of failure.

The second segment examines the relationship between the importance rank of a task and the DFS efficiency. The serviceability efficiency of a service task is determined by comparing the total time of the task to the theoretical minimum time needed to complete the task. The total time and the theoretical minimum time to perform a particular task is determined by using the databases developed by Subramani and Whyland. [1,2] A tentitive conclusion of the present work is that if the efficiency of the task is equivalent to the importance rank, then the service procedure is of acceptable quality. However, if the efficiency of the service procedure exceeds its importance rank, then perhaps it is valid to sacrifice some of its service efficiency to increase the efficiency of another task. In this way, the total service efficiency of a product can be maximized by optimizing each task according to its relative improtance.

Lastly, several case studies will be used to demonstrate the complete DFS strategy procedure shown Figure 1.1.

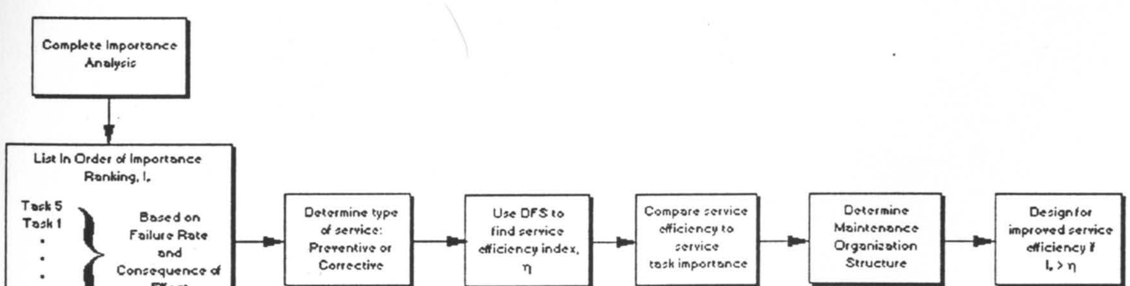

Figure 1.1: DFS Strategy

1.3 Report Layout

The following chapters describe how the DFS strategy was developed and validated. Chapter 2 briefly reviews some terminology common to serviceability, maintainability, and reliability. Chapter 3 contains a procedure to determine which tasks are most important from a serviceability standpoint. It also contains a method to classify each procedure, whether it be corrective or preventive, and to determine at what level the product should be repaired. Chapter 4 discusses some additions to the DFS database aand investigates a relationship between service task efficiency and importance rank. Chapter 5 contains several case studies which are used to demonstrate how the procedures developed can be applied to actual products. Chapter 6 summarizes the work completed for this thesis and suggests related areas for future work.

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Chapter 2: Terminology & Theory

During the initial literature search in maintainability, it was determined that each source often used different terminology in reference to the same subject. Hence it was necessary to establish standard terminology that will be used throughout this report. This chapter contains relevant terminology, basic reliability theory and a brief description of maintainability aspects. The terminology was adapted from references [1,2,3,4,5,6].

2.1 Terminology

A *system* is any group of items that work together to perform a certain operation.

A *mission* is the task that the system is intended to perform.

A *failure* is any occurrence that impedes the system from properly carrying out its intended mission until appropriate corrective action is taken. Failures can range from a complete termination of operation, to a gradual reduction in performance below acceptable limits.

A *failure source* is the lowest level component to which the failure of a system can attributed. The ultimate failure source is a faulty part or faulty connection between parts or assemblies whose physical decay caused the failure. Because it is not always possible to purchase individual components from the manufacturer, a *component* in the present work, is defined as the lowest level part or subassembly which can be purchased from the supplier. Thus a failure source may or may not be an individual part. If a failure source can be attributed to a part that can not be purchased separately, then the failure source becomes the subassembly in which the failure ultimate failure source is contained.

A *failure mode* is any one of the ways in which the given system may fail. For example, degradation of piece parts in a printer can cause the printer to fail in several different modes ranging from complete cessation of operation to a reduction in print quality below an acceptable limit.

Operating life or design life refers to the time span in which a product can be expected to operate safely and meet specified performance requirements if it is maintained according to the manufacturer's instructions and it is not subjected to stresses beyond the design limitations. A product's operating life may or may not be terminated by a failure occurring. This judgment depends upon the type of product involved and the way in which the product is being used. In those cases in which a component's operating life may be significantly shorter than that of the product in which it is installed, and the product depends on the operation of the component, the product can be expected to fail before its expected life has expired. However, this failure source can be eliminated by replacing the component before its expected operating life limit has been reached. Operating life can be expressed in operating hours, calendar years, cycles to failure, or any other unit appropriate for the system under consideration. A product may continue to function after the design life has elapsed because the design life is determined by the product manufacturer as expected value to the consumer.

A *limited-life component*, is a component with an anticipated operating life less than the expected operating life of the system in which it is contained. For example if the operating life for a system is three years and the operating life for an item in that system is two years, it would then be considered a limited-life component. The significance of a limited-life component is that the item will be expected to fail before the usefulness of system is lost.

Preventive service, consists of those service tasks performed in order to prevent or delay expected failures. Preventive service can be broken down into two categories; routine maintenance and scheduled replacement.

Routine maintenance tasks are those that must be performed to assure that an item will remain in proper operating condition.

1. Replacement of consumables such as fuel, and depletables such as lubricants, lead-acid battery electrolyte, coolant fluid, air in tires.
2. Minor adjustments and alignments.
3. Cleaning of permanent filters and other critical surfaces subject to contamination.
4. Replacement of expendable filters and other short lived items.

Scheduled replacement applies to components that meet the following criteria:

1. Failure of component would endanger personnel or equipment or would reduce the operating availability of product below minimum acceptable limit.
2. It is a limited-life component with an expected life substantially less than the intended operating life of the product.

Corrective service, consists of those service tasks performed in order to return the product to a satisfactory operating level after a failure has occurred. An example of corrective service could be replacing a burned out headlight or changing a flat tire. Corrective service tasks usually occur in an unscheduled and random fashion.

Failure rate is a measure of the average number of failures expected from an item or group of items over a period of time.

2.2 Reliability Theory

Reliability is the probability that a system or component of a system will complete the required mission at any time during the systems life. The fundamental equation of reliability is based on a constant failure rate and describes time to failure by an exponential density function of the form

$$R(t) = e^{-\lambda t} \tag{2.1}$$

Where t is the time duration of the system's mission and λ is the failure rate of the item throughout the span of the mission.

Every part has a characteristic failure rate pattern which can be determined from data collection during testing or derived from warranty records. The failure rate for any given part is determined by three factors: (1) the design of the part; (2) the quality standards to which the product was manufactured; (3) the operating conditions to which the part is subjected to during its service life. The failure of products over their entire lifetime can often be classified into three major categories of failures:

1) Quality failures occur early in the life cycle and are due to quality defects in the manufacturing process or as a result from poor design.

2) Stress related failures occur at random times during the systems lifetime and are caused by the application of stresses which exceed the design requirements.

3) Wearout failures which occur as the system nears the end of its useful life and begins to wear out.

When the three failure mechanisms are summed over the lifetime of the product, the bathtub curve for reliability is generated. A graph of a general population's failure rate over time is shown in Fig. 2.1. [1] The bathtub curve can model the reliability of an individual piece-part type or that of an assembly of parts. However, the failure rate for an assembly of parts is a function of the failure rate of the individual component parts and may vary from the shape of the curve shown in Fig. 2.1

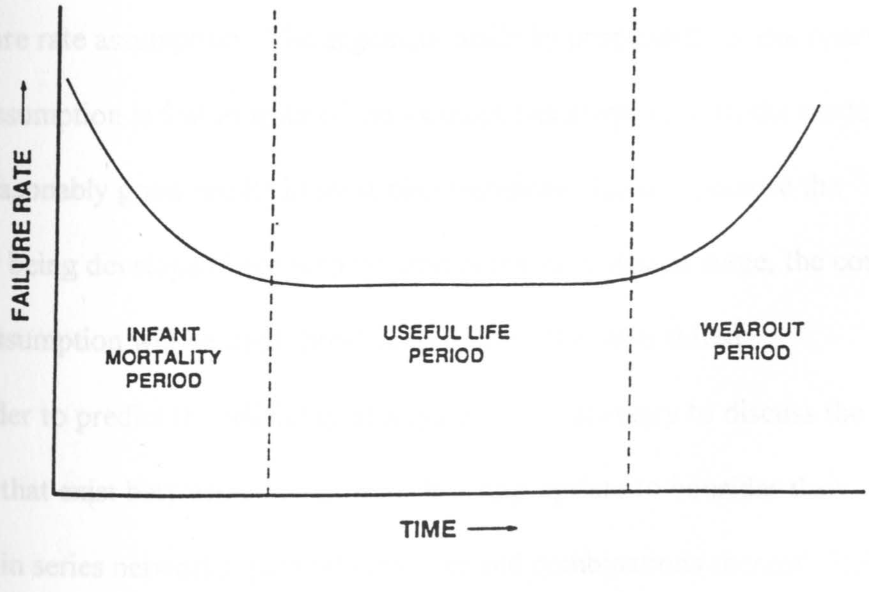

Figure 2.1: Generic Bathtub Curve

Constant failure rates and exponential failure distributions are commonly used in reliability calculations because reliability analysis using constant failure rates is much easier than performing the analysis with other failure rates.

A constant failure rate is often assumed when the system is in its useful life stage. The exponential failure relationship for reliability is most commonly used in describing the behavior of electrical components. However, research has shown that mechanical systems have approximately constant failure rates if they are made up of a number of subcomponents with different failure rates [2].

Constant failure rates may also be used when failure data is so sparse that a more exact determination of the failure function can not be made. It is also necessary to note that a constant failure rate suggests that previous use of the component does not affect the failure rate; in other words it is assumed that the failure rate does not increase with time. However, components do degrade with time, and this is a direct contradiction of the constant failure rate assumption. The argument made by proponents of the constant failure rate assumption is that in spite of the assumptions involved with the model it seems to provide reasonably good results in most circumstances. Hence, because the methodology being developed here is to be used in the early design stage, the constant failure rate assumption will be used throughout unless otherwise stated.

In order to predict the reliability of a system it is necessary to discuss the relationships that exist between components. It is appropriate to consider their relationships in series networks, parallel networks and combinations thereof. Reliability networks are used in block diagrams and static models used for reliability prediction and analysis.

A series relationship is probably the most commonly used and is the easiest to analyze. In a series network all components must function properly if the system is to operate correctly. Assuming that Fig. 2.2 contains diagram of series network which includes subsystem A, subsystem B and subsystem C, the reliability of the system is the product of the reliabilities of the individual subsystems and may be expressed as

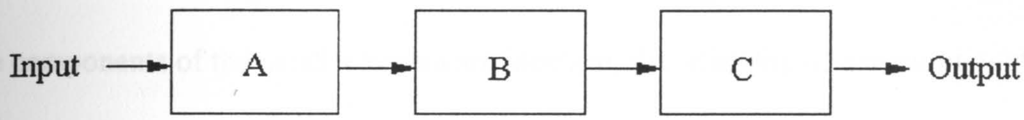

Figure 2.2: Series Network Configuration

$$R_S = R_A \times R_B \times R_C \tag{2.2}$$

Hence, with reference to Eq. (2.1), the failure rate of a series network system can be calculated by

$$\lambda_S = \sum_{i=0}^{i=n} \lambda_i \tag{2.3}$$

The failure rate, λ_s, can then be substituted into Eq. (2.1) to calculate the reliability of the system.

When considering a parallel network predicting the reliability becomes somewhat more difficult. A pure parallel network is one where a number of the same components must fail in order for the system to fail. A parallel network containing three components is illustrated in Fig. 2.3. The reliability of the parallel network shown above is calculated by

$$R_S = 1 - (1 - R_A) \times (1 - R_B) \times (1 - R_C) \tag{2.4}$$

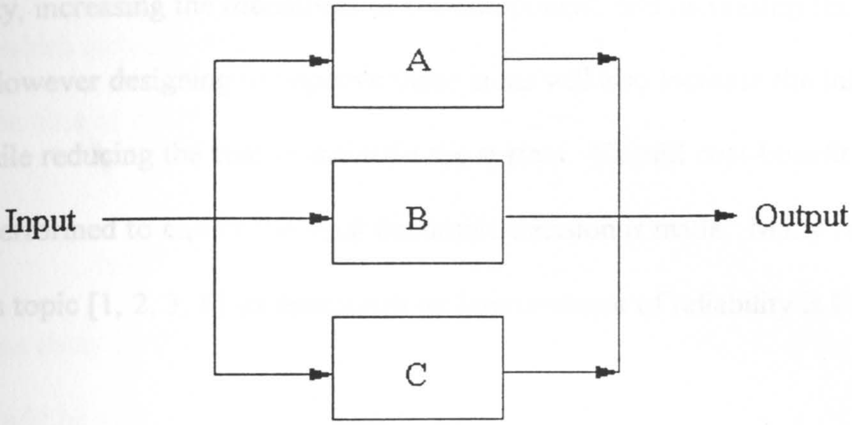

Figure 2.3: Parallel Network Configuration

If the components of the parallel system are identical, the reliability of a network with n components is given by

$$R_S = 1 - (1 - R)^n \tag{2.5}$$

Parallel networks are primarily used to increase the system reliability as Eqns. (2.4) and (2.5) indicate mathematically.

Combined series-parallel networks require that first the redundant parallel elements be combined into a single unit reliability. Then the overall system reliability can be determined by calculating the product of the series reliabilities.

Unreliability or what is sometimes referred to as the failure probability, is the complement of reliability. If the reliability at time t is $R(t)$, then the unreliability or failure probability at time t is given by

$$U(t) = 1 - R(t) \tag{2.6}$$

With this definition the improvement in unreliability of a parallel system can be shown explicitly by substitution into Eq. (2.5); i.e.

$$U_S(t) = [U(t)]^n \tag{2.7}$$

Improvements in reliability can be made by focusing design efforts in increasing initial quality, increasing the robustness of the component, and increasing the durability of the item. However designing to improve these areas will also increase the initial cost of the item while reducing the cost to maintain the system. Careful cost-benefit analysis should be performed to ensure the most economic decision is made. Many references exist on this topic [1, 2, 3, 6] so discussion on improvement of reliability is limited to the above.

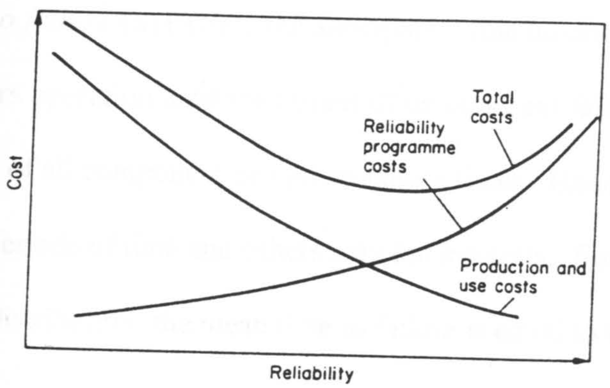

Figure 2.4: Relationship Between Levels of Quality and Cost

2.3 Maintainability Measures

Maintainability is a design characteristic dealing with the ease, accuracy, safety, and economy in the performance of maintenance functions. Maintainability can be measured in terms of elapsed times, maintenance frequencies, maintenance cost, and personnel labor hour rates.

Mean downtime (MDT) is the length of time from the instant the failure occurs until the time the component is returned to operation after repair.

Mean time to repair (MTTR) is the time needed to carry out the actual repair of the system, which includes the time taken to detect the fault, the time to carry out the repair and the time to perform any preoperational testing. Its relation to the total mean downtime is

$$\text{MDT} = \text{MTTR} + \text{miscellaneous delay} \tag{2.8}$$

Miscellaneous delay can be attributed to any time not spent repairing the system. Examples could be waiting for parts or waiting for properly trained personnel.

Mean time to failure (MTTF) is the anticipated time duration between the instant the component enters operation until the instant of its very next failure. The mean time to failure is an average of all component or system failure times. Hence, some systems will only fail after long periods of time and others may fail instantly. For a constant failure rate and an exponential distribution, the mean time to failure is equal to the inverse of the failure rate.

$$\text{MTTF} = \frac{1}{\lambda} \tag{2.9}$$

Mean time between failures (MTBF) is the time duration between two consecutive failures.

$$\text{MTBF} = \text{MTTF} + \text{MDT} \tag{2.10}$$

Operational availability is the probability that an item is functioning correctly at any given point in time.

$$\text{A}_\text{O} = \frac{\text{uptime}}{\text{uptime} + \text{downtime}} \tag{2.11}$$

or

$$A_O = \frac{MTTF}{MTTF + MDT} \tag{2.12}$$

However, the mean dowtime in the operational availability equation may be misrepresenting the potential 'true' availability of the system. Since the mean downtime considers miscellaneous time spent, it includes times that could be potentially eliminated from the analysis. Hence, the inherent availability of the system can be defined as

$$A_I = \frac{MTTF}{MTTF + MTTR} \tag{2.13}$$

An example of availability will be used to further illustrate the need for separate definitions of availability and is shown in Table 2.1.

Operational availability fails to identify a difference between systems B and C even though the MDT is significantly different. If the miscellaneous time spent during the mean downtime of system C could be reduced, then the operational availability of the

Table 2.1: Availability Example

System	A	B	C
MTTF (hrs)	1000	1000	1000
MDT (hrs)	1	90	90
MTTR (hrs)	1	90	1
A_O	0.999	0.9174	0.9174
A_I	0.999	0.9174	0.999

system could be drastically increased. Conversely in order to increase the availability of system B, efforts would be focused on designing the system to reduce the amount of time spent repairing the system. Unavailability of a system or component is the complement of the availability and can be calculated similarly to the unreliability.

Substantial amount of literature exists on the subject of reliability and associated topics. The above description was attended to provide a minimum background of material.

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Chapter 3: Service Task Identification and Classification

Obviously not every service procedure can be examined, therefore, this chapter outlines a methodology developed to aide the service engineer in determining which service tasks should be examined based on their importance. Also, the nature of the task, whether it be corrective or preventive, is determined. Several other aspects of service procedures, such as who will be performing the repair, and where the repair will be conducted are also determined.

3.1 Failure Modes and Effects Analysis

Failure modes and effects analysis (FMEA) is a procedure that identifies potential component failures and assesses their effect on the system. [1] If the criticality of the effect is also considered in the analysis, the analysis is then referred to as the failure modes, effects, and criticality analysis (FMECA). [1] A FMEA or FMECA analysis is used to detect potential weak spots in the system design and improve them through design changes focused on increasing the reliability of the system.

Questions considered during FMEA analysis vary depending on the system being analyzed as well as the scope and purpose of the analysis. However the following five questions are typically considered for every part of the system. [1]

1. How can the component fail? (There could be more than one mode of failure.)
2. How often will the component fail?

3. What will be the effects of the failure?

4. How critical are the consequences of the failure?

5. How will the failure be detected?

In completing an FMEA, all failure modes are identified, their detection documented, frequency of failure recorded, and their effects on the system as well as the potential criticality of failure are considered.

Failure modes and effects analysis attempts to do all of the following [1]:

1. Ensure that all conceivable failure modes and their effects are understood.
2. Assist in the identification of design weaknesses.
3. Provide a basis for comparing design alternatives during the early design stages.
4. Provide a basis for recommending design improvements.
5. Provide a basis for corrective action priorities.
6. Provide a basis for implementing test programs.
7. Assist in trouble shooting existing systems.

A well prepared FMEA will benefit the design team by identifying any weak spots in the system design allowing the team to improve the system reliability by focusing design efforts in these areas.

3.2 Fault Tree Analysis (FTA)

Fault tree analyses are probably the most widely used methods for determining system reliability. FTA is a formal procedure that is capable of determining various combinations of component failures that could cause the occurrence of a failure on the system level. A fault tree is composed of a top event or a system failure at the apex and various system events connected by a series of logic gates along the branches.

Similar to a FMEA, a fault tree is constructed to determine the possible causes of failures or to evaluate the adequacy of the system design. It demonstrates how component failures can propagate through a system to cause a system level failure. A key purpose of performing this type of analysis is to determine whether a design is likely to have an acceptable level of reliability, availability and safety. Because of the complexity of constructing a fault tree analysis for even simple products, further explanation of the procedure has not been included here. More information about fault tree analysis and their construction can be found in the literature. [1,2]

3.3 Service Task Importance Analysis

When considering serviceability in the early design stage it is important to be able to identify were effort should be focused to increase the systems serviceability. Obviously the service task efficiency of every part can not be considered, therefore a procedure is needed to determine where the resources available to increase serviceability of a product should best be applied. Important factors that determine the level of serviceability which should be designed into a product are the frequency with which different failures are likely to occur and the consequence(s) of the failures occurring. The more frequently that a failure occurs , the simpler the service procedure should be to perform, and likewise the greater the consequences of a failure, the simpler should be the procedures for preventive maintenance.

The service task importance analysis proposed here is similar in format to a failure modes and effects analysis. It is intended to complement FMEA, since its focus is to increase the efficiency of the necessary service tasks after all possible reliability improvements have been made. Also in the course of an FMEA analysis, many of the inputs for the service task importance analysis will already have been determined. In order to facilitate the analysis a worksheet shown in Fig. 3.1 was developed. It is intended that this analysis will be performed by starting with the main assembly, then proceeding through the product structure, analyzing any subassembly that is considered to be repairable.

Application of the worksheet is described below; elements of the worksheet are described with reference to the numbers encircled on the worksheet shown in Fig 3.1. Before attempting to complete the worksheet it is necessary to construct an assembly structure chart. It is also recommended that all information pertaining to product failures be gathered in advance using FMEA or similar procedures.

1) Name

Enter the name of the system being analyzed and the name of the next higher level assembly when applicable.

2) Part Identification Number

Enter the identification number of the system being analyzed along with the number for the next high level assembly.

Entry	Name 1	Id. Number	MTTF	Function of System	IA #
System being analyzed		2	3	4	5
Next higher assembly					

6 Failure Source	FF (per/yr)	MTTF 8	Freq. Rank	Function of Failure Source 10	Potential Failure Mode 11	12 Effect of Failure	Con. Rank	Potential Cause 14 of Failure	Import. Rank	Service Eff. (%)
	7		9				13		15	16

MTTF - Mean time to failure (1/failure rate)
FF - Failure frequency failures per year
Importance Rank = Frequency rank x Consequence rank

Figure 3.1: Importance Analysis Worksheet

3) MTTF

Enter the mean time to failure for the system under consideration and the next higher level assembly. On this example worksheet the units given for mean time to failure is years, but any units appropriate for the system being analyzed can be used.

4) Function of System

Enter the intended function or mission of the system and the next higher level assembly.

5) IA Number

Enter the number of the service task importance analysis so that the worksheet can be tracked and found again if necessary.

6) Failure Source

Enter the name of the part or subassembly being considered in the analysis. If a subassembly is being considered, it may be necessary to conduct a separate analysis for the components of the subassembly if it is considered repairable.

7) Failure Frequency (FF)

Enter the failure frequency for the failure source identified in Step 6. The failure frequency is the number of system failures that can be attributed to the failure source. For example if the system has a failure rate of 10% per year and the failure source causes 33% of those failures per year, then the failure frequency is equal to 3.3% or 0.033 system failures per year.

8) MTTF

Enter the mean time to failure for each failure source under consideration. It is simply the inverse of the failure frequency

9) Frequency Rank, F_r

The number for the frequency rank is placed into this column. The frequency rank is a number used to compare the likelihood of different component/subassembly failures. A suggested failure ranking scheme is given in Table 3.1.

10) Function of Failure Source

Enter the function of the item under analysis. If the item has more than one function with different potential modes of failure, list all the functions of the item separately.

Table 3.1: Failure Frequency Ranking

Rank, F_r	Likely Failure Rate
10	Failure occurs one or a few times per week
9	Failure occurs one or a few times per month
8	Failure occurs a few times per year
7	Failure frequency 0.5 to 0.2 per year
6	Failure frequency 0.2 to 0.1 per year
5	Failure frequency 0.1 to 0.05 per year
4	Failure frequency 0.05 to 0.01 per year
3	Failure frequency 0.01 to 0.005 per year
2	Failure frequency 0.005 to 0.002 per year
1	Failure very unlikely - FF < 0.002 per year

11) Potential Failure Mode

Potential failure mode is defined as the manner in which a component, subsystem or system could potentially fail to meet the design requirements. The potential failure mode may also be the cause of a potential failure mode in a higher level assembly, or be the effect of one in a lower level component. If a component or subassembly has more than one potential failure mode list each one separately.

12) Effect of Failure

Effect of failure is defined as the effects of the failure mode on the function of the system, as perceived by the customer. The effects of the failure should be described in terms of what the customer might notice or experience. The effects should always be stated in specific terms relative to the system, subsystem or component being analyzed.

13) Consequence Rank, C_r

Consequence rank is an assessment of the seriousness of the effect of the potential failure mode to the next component, subassembly, system or to the customer if it occurs. Consequence rank applies to the effect only. A suggested consequence ranking scheme is given in Table 3.2. It is important to notice that the suggested ranking scheme does not just focus on the possible effects on the system or involved people, but also includes the economic consequences of failure to the end user. If the end-user's business depends on the system for economic survival, the failure of the system becomes significantly more important than if the failure has little effect on business even though the system may still be inoperable.

Table 3.2: Failure Consequence Ranking

Rank, C_r	Criteria for Consequence Ranking
10	Catastrophic failure with no warning and a high probability of personal risk.
9	Total loss of operating capability causing substantial economic damage or posing personal risk.
8	Total loss of operating capability causing major disruption to important activity or causes major damage to other items.
7	Total loss of operating capability causing minor disruption to important activity or causes minor damage to other items.
6	Total loss of operating capability.
5	Performance severely effected by failure.
4	Significant loss of performance.
3	Minor effect on performance.
2	Slight effect on performance.
1	No effect.

14) Potential Cause of Failure

Potential cause of failure is defined as an indication of a design weakness, the consequence of which is the failure mode. List every conceivable cause of failure for each failure mode. Although knowing the cause of the failure has little impact on the serviceability of the system, it is important that the service engineer realizes the potential cause of the failure. Some typical causes may include, but are not limited to:

Inadequate design life assumption

Over-stressing

Corrosion

Wear

Poor quality in manufacturing

15) Importance Ranking Number

The importance rank is a number that signifies the importance of designing for quick and easy service of the particular failure source under consideration. Importance rank, I_r, is calculated by multiplying the frequency rank and the consequence rank numbers; i.e.

$$I_r = F_r \times C_r \tag{3.1}$$

which yields a number between 1 and 100. The higher the importance rank, the easier to perform should be the associated service task. In general, regardless of the resultant importance rank, special attention should be given to items when the frequency of failure and/or the consequence of failure are high. Suggested service quality evaluation criteria are given in Table 3.3 below. Similarly to the

Table 3.3: Quality of Serviceability Design Requirements

Criteria	Service Quality Category
$I_r > 70$	Design for obvious diagnosis and easiest possible service procedure. Service task efficiency very important due to high frequency and high consequence of failure. Necessitates the use of fasteners designed for rapid disassembly, easy access to service locations, minimization of the number of unrelated items to be removed, and so on. Preventive maintenance schedules necessary.
$50 < I_r \leq 70$	Rank necessitates efficient service procedure and some diagnostic capability. The use of threaded fasteners should be avoided, no permanent fastening methods allowable, easy access to service location should be enabled. Preventive maintenance schedules recommended.
$30 < I_r \leq 50$	Changes in design to improve upon serviceability efficiency are recommended. Use of threaded fasteners should be avoided but permanent fastening methods should not be considered an option.
$15 < I_r \leq 30$	Serviceability should be considered but major changes in design for service improvements are not justifiable. Investigate improvements that will increase manufacturability and serviceability.
$I_r \leq 15$	Do not compromise manufacturing efficiency for increased serviceability. Investigate improvements that will increase manufacturability and serviceability. Permanent fastening methods may be acceptable.

frequency rank and the consequence rank, it should be emphasized that requirements may vary between different industries and the criteria should be modified as necessary.

16) Service Efficiency (%)

The service efficiency is a time based measure used to compare the proficiency of procedure with the theoretical ideal service task. Calculation of this measure is described in Chapter 4 and further discussion will be continued there.

3.4 Service Plan Development

After the appropriate service tasks have been identified, a service plan must be developed. An integral aspect of developing a service plan is to classify the type of task that is to be performed. As discussed in Chapter 2, there are two distinctly different types of service tasks, preventive and corrective. It is necessary to determine which types of tasks are going to be performed in order to complete the development of a plan for the serviceability of the system. If a preventive maintenance task is determined to be necessary, then it will also be necessary to decide whether it could be done as part of routine maintenance or as a scheduled replacement as defined in Chapter 2.

Another essential component of developing a service plan is to determine 'who' will be servicing the product and at what location the product will be serviced. For example, the end-user might service in their home, a trained technician may service in a special facility or it may be essential for it to be returned to the manufacturer. This service level depends mainly on the complexity of the task and the function of the system being serviced.

3.4.1 Service Task Classification

With an accepted organization structure in place, attention can be focused on determining whether a task is considered preventive or corrective. In order to make this determination, a series of questions is answered, the responses to these questions then determine whether the task is to be performed as a preventive or a corrective task. These questions are given in Fig. 3.2 in the form of a flow chart. An explanation of the questions presented in Fig. 3.2 follows:

1) Can failure be deferred by performing routine maintenance? This question asks if by performing a task that falls into the category of routine maintenance, as defined in Chapter 2, that the failure of an item or system can be deferred. An example of this may be changing the oil in a car in order to defer the failure of the motor. If the answer is yes, then task should be scheduled at appropriate intervals. However, if the answer to this question is no then proceed to the next question.

2) Is the failure caused by a limited-life component? An answer of yes for this question allows the user to proceed further in the analysis while an answer of no classifies task as corrective. Therefore the failure source should only be replaced after it has failed.

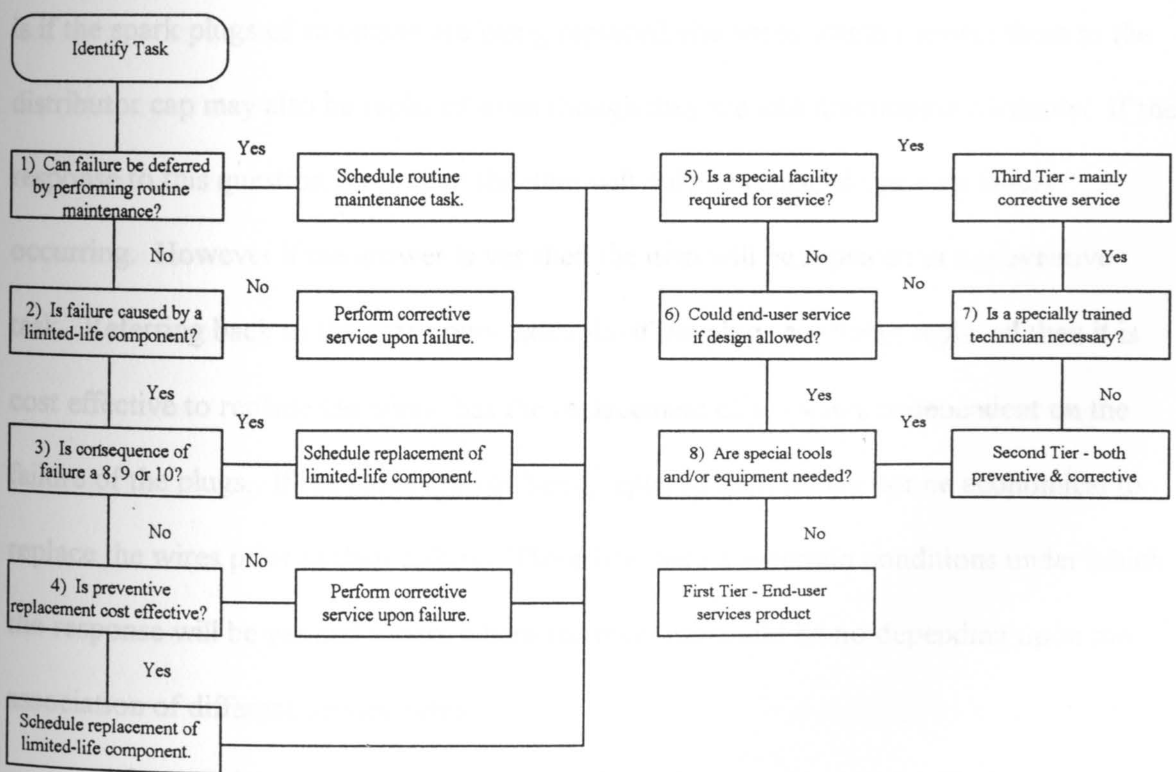

Figure 3.2: Task Classification Flow Chart

3) Is consequence of failure a 8, 9 or 10? This question reveals the severity of failure if the component was allowed to operate until failure. The 8, 9 or 10 ranking should be obtained from the analysis described earlier in this chapter. If the consequence is high, then the item should be replaced in a preventive manner prior to failure. If the consequence of failure is low, then continue to the next question.

4) Is preventive replacement cost effective? It has already been determined that the consequence of failure is low, so it has to be decided whether or not it is cost effective to perform preventive service. For example, many printers are sent to the manufacturer for service. Hence, the manufacturer may decide that it is cheaper to replace several items besides the failure source while they have the printer in their possession. Another example is if the spark plugs of an engine are being replaced, the wires which connect them to the distributor cap may also be replaced even though they are still functioning correctly. If the response to this question is no, then the item will only be replaced upon its failure occurring. However if the answer is yes then the item will be replaced in a preventive task. Referring back to the spark plug example, if the plugs are being replaced then it is cost effective to replace the wires, but the replacement of the wires is dependent on the failure of the plugs. If the plugs are not being replaced then it may not be economical to replace the wires prior to their failure. Therefore there are certain conditions under which the response will be yes and others where the response could be no depending upon the association of different service tasks.

After a task is designated to be corrective, it is necessary to identify the specific type of corrective service to be performed for each failure mode. Moss [3] has developed a flow diagram, shown in Fig. 3.3, to demonstrate the Corrective Maintenance Analysis Procedure. The first three questions deal with the corrective service performed on the failure source; the other three questions identify how the failure source will be dealt with. Responses to each question asked in Fig. 3.3 should be made as explained below.

1) Can failure be corrected by adjusting, aligning, or calibrating the failure source? The answer will be yes only if the failure can be corrected without any physical rework or replacement of any of its components. Consider removing a piece of jammed paper from a copier as an example. If the answer is no, then proceed to the next question.

2) Can failure be corrected by repairing the failure source in-place? The answer will be yes if the failure source can be repaired by physical rework, with no replacement of any of its components. If the answer is no, then proceed to the next question. Although the category of corrective action, repair in place, is intended to apply to repair of the failure while it remains in place, it must also include the repair of items removed in order to facilitate rework. An example could be removing spark plugs from an engine for cleaning and regapping.

3) Should failure be corrected by replacing the failure source? By answering no to the first two questions, it has been indicated that the failure can not be corrected by simply adjusting or repairing the failure source in place. Therefore, it can be assumed that the failure can only be corrected by replacing the faulty component itself. The failure source maybe an entire subsystem or a single component of that particular subsystem. Answering no to this question implies that the component being analyzed is a assembly and its components should be analyzed further.

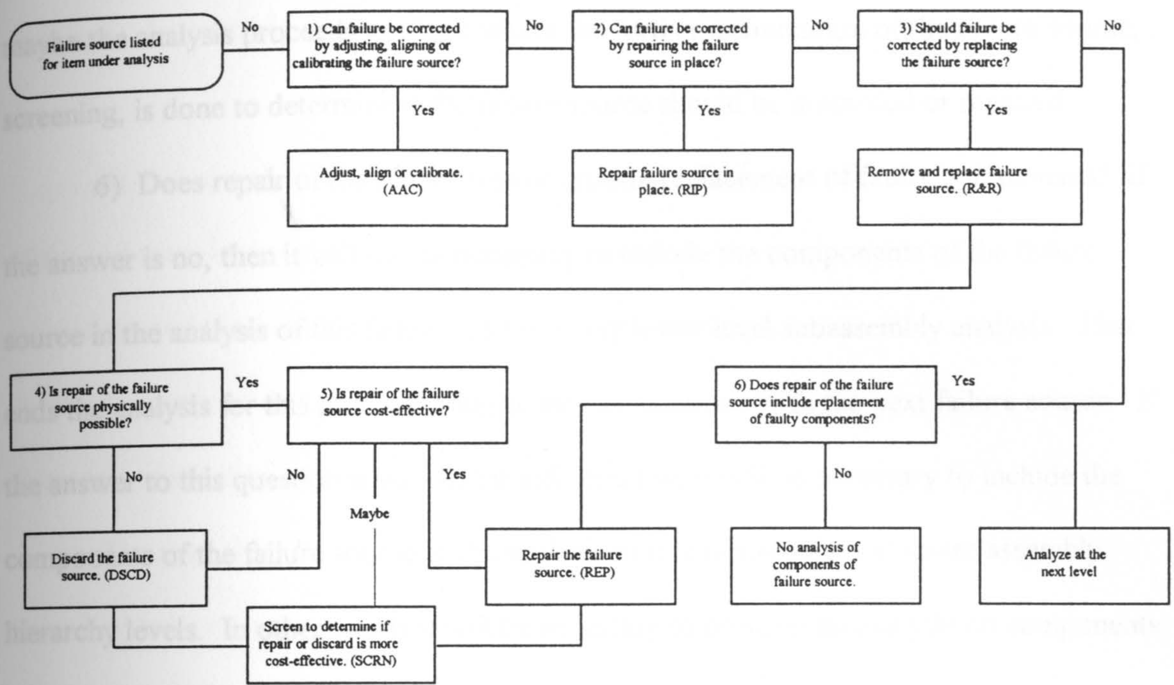

Figure 3.3: Corrective Maintenance Analysis Procedure

4) Is repair of the failure source physically possible? Certain items will always be unrepairable upon a failure occurring. Others may be designed such that the permanent fastening methods during the initial assembly prohibit possible repair. With an answer of yes the analysis continues, but a no response ends the analysis for this failure source by designating the failure source to be discarded.

5) Is repair of the failure source cost-effective? According to Moss [3], there are three possible answers to this question - yes, no, and maybe. The answer will be either yes or no in cases where the consequences of the failure are fairly constant. However, in more complex situations where the potential damage caused by the failure occurring is unknown and the only way to determine the extent of the failure is to examine the system, an answer of maybe must be used. An answer of no ends the analysis for this failure source by discarding it and an answer of yes designates the failure source for repair. By answering

maybe the analysis proceeds to block where the further examination of the failure source, screening, is done to determine if the failure source should be discarded or repaired.

6) Does repair of the failure source include replacement of faulty components? If the answer is no, then it will not be necessary to include the components of the failure source in the analysis of this failure source in any lower level subassembly analysis. That ends the analysis for this particular failure source, continue with the next failure source. If the answer to this question is yes then it indicates that it will be necessary to include the components of the failure source in the analysis of this failure mode at lower assembly hierarchy levels. In other words it will be necessary to perform an analysis on components of the subassembly currently being analyzed. This maybe necessary for several reasons, one of which maybe that the subassembly itself contains one or more subassemblies that must be analyzed in order to complete this analysis.

3.4.2 Service Level

After answering the previous question, every possibility has been considered and the service task is now classified as preventive or corrective. The concept of a service organization structure has been developed and will be introduced to complete the final step in setting up a planning procedure, which is to determine 'where' the product will be serviced and 'who' will service it. [3,4]

At the lowest tier, servicing and minor repairs are performed by the end user in accordance with an owner's manual. No special tools, test equipment, or facilities are required, and the necessary replacement parts or assemblies are readily available from local suppliers. An example on a printer might be replacing the ink cartridges after they have run out.

At the second tier, preventive or corrective service, normally beyond the capability of the end user, is performed by an independent shop. This level generally requires trained technicians and the use of special tools or test equipment and the replacement parts may have to be obtained from the manufacturer. An example of this tier could be the local electronic repair shop or the local garage.

The third tier performs mainly corrective service tasks that may require specially trained technicians or require special facilities and equipment. The division between the second and third tier is not fixed and it may vary depending on the circumstances. Under certain circumstances the third tier may be the original manufacturer of the product, such is the case with some printer manufacturers.

Referring to back to Fig. 3.2, the responses to questions five through eight will determine the necessary information to complete the analysis. An explanation of the questions follow.

5) Is a special facility required for service? If a special facility is required to repair the system then it must be repaired at the third tier. A special facility could be necessary to contain special tools and/or equipment that for some reason could not be supplied to a lower service tier. For example the cost of a piece of equipment may be so expensive that is not economically feasible to have more than a few built.

6) Could the end-user service the product if design was appropriate? This question suggests that if the product was designed for ease of service the end-user may

then be able to repair the product. In some cases a product could be designed for service and yet the end-user would not be able to repair the system because of the system complexity.

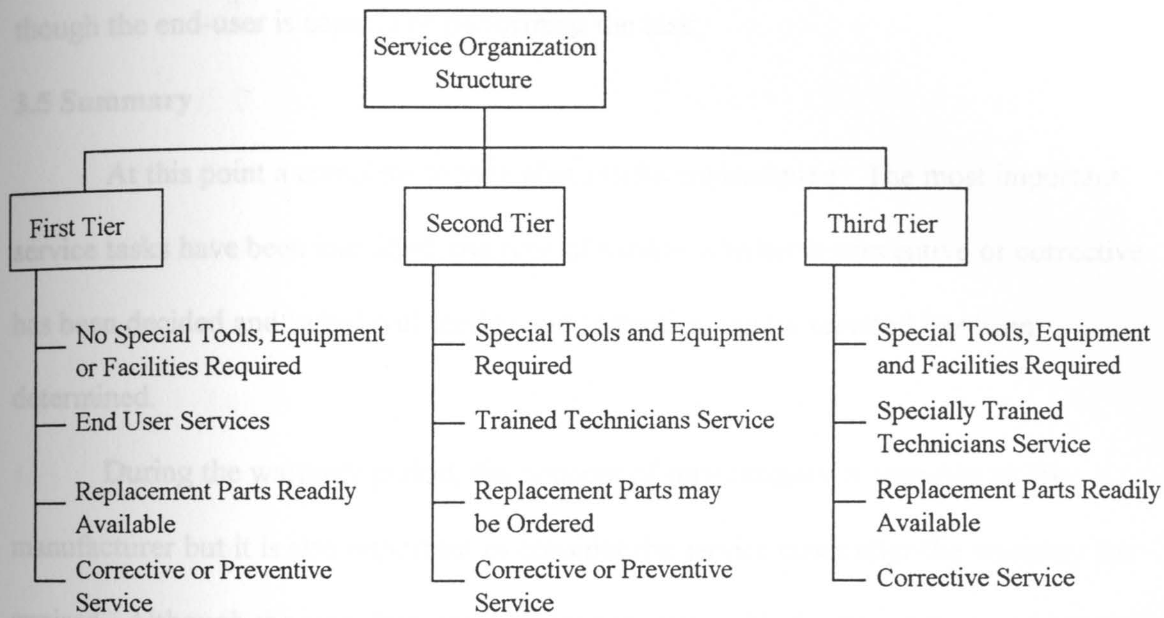

Figure 3.4: Service Organization Structure Chart

7) Is a specially trained technician necessary? This question is intended to determine if the system is so complex that a specially trained technician is needed rather than just a trained technician. For example an automobile mechanic is considered a trained technician, but a commercial airplane mechanic may be considered a specially trained technician. A positive response indicates that the service will likely be performed at the third tier. While a negative answer implies that the service will occur at the second tier because the end-user is incapable of repairing and a specially trained technician is not necessary.

8) Are special tools and/or equipment needed? Many times the only reason why a system is serviced at special locations is the need for special tools and/or equipment. If

the need for these tools and equipment is eliminated then the system could be serviced at a lower tier. If special items are not required, then the end-user will likely carry out the service. However if they are required then a second tier system will have to used even though the end-user is capable of performing the task.

3.5 Summary

At this point a complete service plan can be implemented. The most important service tasks have been identified, the type of service whether it preventive or corrective has been decided and 'who' will service and 'where' it will be serviced has been determined.

During the warranty period, the concern of serviceability is apparent to the manufacturer but it is also important to consider the service costs after the warranty has expired. Although the manufacturer is no longer responsible for the cost, the consumer is and their impression of the product may influence future purchase decisions.

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Chapter 4: Extensions of the DFS Methodology

While analyzing case studies for this project, the need to examine several other additional areas became apparent and will be discussed here. First, a new service efficiency measure was proposed and a link between service importance and efficiency was developed. Second, the application of progress functions to maintenance operations was investigated. Third, application of the DFS methodology was extended to allow economic decisions to be made between component and subassembly replacement. Lastly, the effect of worker position on service time was investigated by performing service procedures in various positions. These extensions of DFS will be described in the following sections.

4.1 Service Efficiency Measure

A design for service efficiency measure, or DFS index, is necessary to facilitate comparisons between service tasks in alternative designs. Although Subramani and Whyland [1,2] have proposed several methods of quantifying service efficiency, they have lacked the means to satisfactorily account for failure rate and consequence of failure. Hence, an attempt to develop a more appropriate evaluation of task efficiency was undertaken. The currently used DFS index [1,2,3] combines the cost of labor with the cost of the service item, as shown in Eq. (4.1), thereby almost eliminating the effect of time for a service task which contains a costly service item. A 'high' index ranking could be obtained even though there could be significant opportunity to reduce the amount of time spent repairing the system.

$$\eta_{cost} = \frac{C_s}{C_s + C_d + C_t + L \times T_s} \qquad (4.1)$$

where η_{cost} = DFS cost based service index

C_s = Value of service item ($)

C_d = Value of discard items ($) (items such as seals that must be replaced simply because they have been disassembled)

C_t = Cost of special tools or equipment required ($)

L = Labor rate ($/sec)

T_s = Estimated time to perform service task (sec)

The cost based index conforms to the perception of service value in that it gives the lowest score for inexpensive items which require long service times. Yet, if the item is inexpensive, and it is very unlikely to fail, then it may be justifiable to bury that item within the product structure. Therefore the failure rate is as important as the cost of the item. However, failure rate alone is not an acceptable indicator of serviceability importance. The consequence of a the failure occurring must also be included in order to obtain a worthwhile measure. By performing the service task identification procedure outlined in Chapter 3, the importance of each task can be determined and then can be compared to the ranking of other tasks.

4.1.1 Time Based Service Index

In order to successfully implement a time based index or efficiency measure, criteria similar to those developed in the DFA methodology [4] for theoretical minimum number of parts must be determined. For serviceability the following three criteria are used to determine if the removal and reassembly of a component can be justified as theoretically necessary. [1,3]

- The part/subassembly removed is the service item or contains the service item and will be replaced as a component.
- The part/subassembly removed or operation performed isolates the service item, or subassembly containing the service item, from other parts and subassemblies in the system with which it has functional connections or is connected to for functional reasons. Typically these connections transfer fluids, electricity, electrical signals, motion or force. An example may be a wire harness connection, drive belt or a fan blade connected to a motor.
- The part/subassembly removed is a cover part or an operation performed reorients a cover part which is necessary for protecting the service item and related parts from the environment. A cover part may also protect the user from potential injury.

Similar to the DFA criteria, when multiple identical tasks exist they must be considered separately. Consider wire harness connections, if a single wire harness is connected to the service item several times, only one connection can be justified. . However, if there are several different wire harnesses connecting the service item to several distinct components, then all of them may be justified because they are necessary to isolate the service item.

Parts/subassemblies removed or operations performed that can be justified based on the above criteria will be comprise those tasks that would be performed for an ideal

$$t_{min} = \frac{2 \times 2.4 + 3.6}{3} + \frac{2 \times 3.8 + 2.2}{3} + 1.4 + 1.4 = 8.87 \approx 9.0 \tag{4.3}$$

The time based efficiency measure can be given as:

$$\eta_{time} = \frac{t_{min} \times N_m}{T_s} \tag{4.4}$$

or

$$\eta_{time} = \frac{9 \times N_m}{T_s} \tag{4.5}$$

where N_m = The theoretical minimum number of parts that can be justified for removal in the service task

T_s = Estimated time to perform service task (sec)

In order to calculate the time-based service efficiency for a system comprised of several service procedures, it is proposed that the separate index values should be weighed according to the expected failure frequencies This gives an expression for system service efficiency as:

$$\eta_{total} = \frac{\eta_1 \times f_1 + \eta_2 \times f_2 + \cdots + \eta_n \times f_n}{f_1 + f_2 + \cdots + f_n} \tag{4.6}$$

where $\eta_1, \eta_2, \cdots, \eta_n$ = Efficiency values for tasks 1, 2, •••, n respectively

$f_1, f_2, \cdots, f_n$ = The failure frequencies for items 1, 2, •••, n respectively

4.1.2 DFS Index Goals

In order to establish serviceability design goals for products, the relationship between DFS index values and the importance ranking values has been investigated. The product chosen for investigation was a new model color printer which the authors believe is in most aspects an excellent design for service. Figure 4.1 contains a completed importance analysis for this color printer. The actual failure rates are confidential and they are not used in this analysis. However, the failure rates given in Figure 4.1 will yield the same frequency ranking number as the actual failure rates, thus retaining the validity of the analysis.

In performing the importance analysis, the most important service tasks for the product were investigated. These tasks were then subjected to DFS analysis including calculation of the time based efficiency measures using Eq. (4.5). The service efficiency measures are given in the last column of Figure 4.1.

Entry		Name			Id. Number	MTTF	Function of System			IA #
System being analyzed		Color Printer			—	0.0141	To produce color print outs			1
Next higher assembly		—			—	—	—			—
Failure Source	FF (per/yr)	MTTF	Freq. Rank	Function of Failure Source	Potential Failure Mode	Effect of Failure	Con. Rank	Potential Cause of Failure	Import. Rank	Service Eff. (%)
Print Mechanism-Paper Out	50	0.02	10	Feed paper to print cartridge	Paper runs out	Printer will not operate	6	Paper supply diminished	60	58.8
Print Mechanism-Paper Jam	12	0.0833	9	Feed paper to print cartridge	Paper jam	Printer will not operate	6	Multiple pieces of paper fed together	54	71.4
Color Ink Cartridge	3	0.3333	8	To provide color ink to paper	Ink runs out	Print quality will deteriorate	5	Cartridge not sealed properly	40	58.8
Black Ink Cartridge	6	0.1667	8	To provide black ink to paper	Ink runs out	Print quality will deteriorate	5	Cartridge not sealed properly	40	58.8
Logic Board	0.015	66.667	4	To control the operation of the printer	Printer will not function correctly	Printer will not work when needed	6	Poor quality component or ESD	24	23
Feed Roller	0.0065	153.85	3	Feed paper to the print cartridge	Clutch breaks	Paper will not feed correctly	6	Over-stressed clutch mechanism	18	1.91
Roller Clutch	0.0065	153.85	3	Facilitate feeding of paper	Mechanism fails	Paper will not feed correctly	6	Over-stressed component	18	1.75
Pinch Rollers	0.02	50	4	Facilitate paper feeding	Rollers wear out	Paper will not feed correctly/not severe	4	Over-stressed or poor quality	16	15.6
Carriage Motor	0.002	500	2	Move print carriage across paper	Motor fails to operate	Printer will not print	6	poor quality	12	11.4

MTTF - Mean time to failure (1/failure rate)
FF - Failure frequency failures per year
Importance Rank = Frequency rank x Consequence rank

Figure 4.1: Importance Analysis

Comparing the last two columns in Figure 4.1 it is clear that a correlation exists between the Importance Rank and the Service Index values. This is illustrated in Fig 4.2

which is a bar chart of the efficiency values of the printer service tasks compared to their Importance Rank values.

When considering the printer design it would appear from the comparison chart that the service tasks of replacing the feed roller or the roller clutch are both candidates for improvement. These tasks are much less efficient than the task of replacing the carriage motor which has the same importance ranking. Thus it is proposed that service importance rank provides a number which can be used to prioritize service tasks. A more tentative, but much more profound supposition, is that the importance rank number can be viewed as a service efficiency goal against which the DFS index value should be compared. This supposition must be further tested through case studies including excellent examples of design for service as well as case studies that are poorly designed for service.

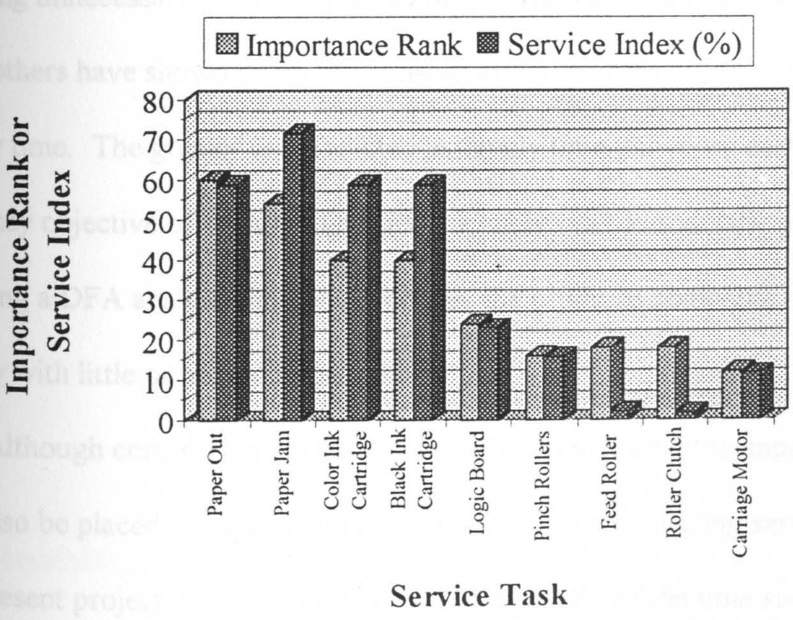


Figure 4.2: Importance Rank vs. Service Index

In essence, the importance rank provides the design team with a number which they can use to determine which tasks need to be examined for service and furnishes them with a task efficiency goal.

4.2 Design Considerations For Serviceability

The best way to increase the serviceability of a product is to reduce the number of failures occurring by increasing the systems reliability. However, increasing the reliability of a product, beyond a certain level, may involve unacceptably large costs in initial manufacturing.

4.2.1 Assembly Simplicity

An important design objective for improving reliability is simplicity. Since every part used in the design has the potential of failing or being assembled incorrectly, a way to increase reliability is to reduce the number of parts. Part reduction is accomplished by eliminating unnecessary parts or by combining parts with others in manufacture. Hinckley [5] and others have shown that a relationship exists between product complexity and DFA assembly time. The greater the predicted assembly time, the more complex the product. Since a key objective of DFA is to reduce assembly time by reducing part count, performing a DFA analysis inherently reduces the products complexity and increases reliability with little or no additional cost.

Although considering the initial assembly of the product is important, emphasis should also be placed on simplifying the reassembly process during service. Case studies, in this present project, have shown that on average 45% of the time spent servicing a product is consumed in the reassembly stage, and only about 30% during disassembly.

Figure 4.3 shows the average time breakdown for all the case studies analyzed in this project. (Note that item set-aside time is included in the item removal time) Since fixtures and other assembly aides are usually not available during service operations, alignment and locating features become even more important. Also reassembly operations in service are more likely to be non-vertical than in initial assembly, so careful consideration must be given to the difficulties involved with the reassembly of the system under these conditions. For example, heavy items such as a washing machine drive motor should incorporate alignment features to allow the technician to fasten the item while supporting the weight of the component. Inadequate alignment considerations will have a significant negative impact on the reassembly time of the service task.

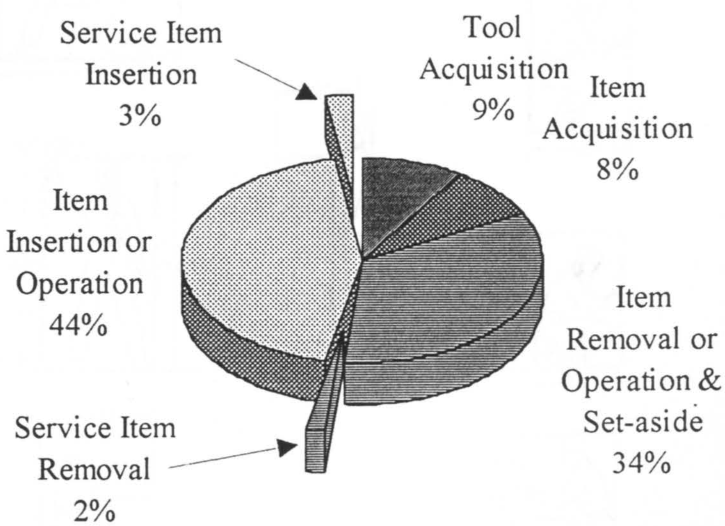


Figure 4.3: Time Breakdown - All Case Studies

4.2.2 Accessibility

Perhaps the most common mistake in product design is that of inaccessibility of service items. Sizes of openings, and access spaces that maintenance personnel have to work within are often inadequate. Also there is often inadequate space for the service operator to get the tool and his hands in the correct position to perform the operation. Because it is impossible to have every part arranged and located to give the greatest accessibility, it is necessary to identify components that will fail most frequently or whose failure will critically effect the systems performance. This can be accomplished by performing the procedure outlined in Chapter 3. Figures 4.4, through 4.7 [6,7] give some access space recommendations for various body positions and common hand tools.

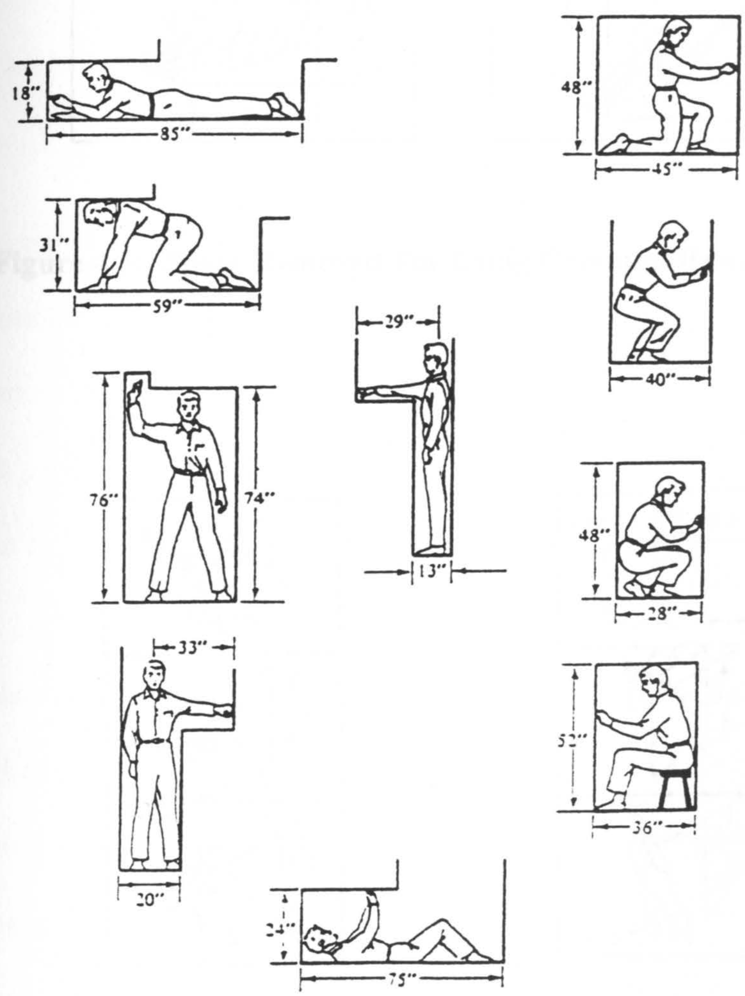


Figure 4.4: Limiting Clearances Required For Various Body Positions [6]

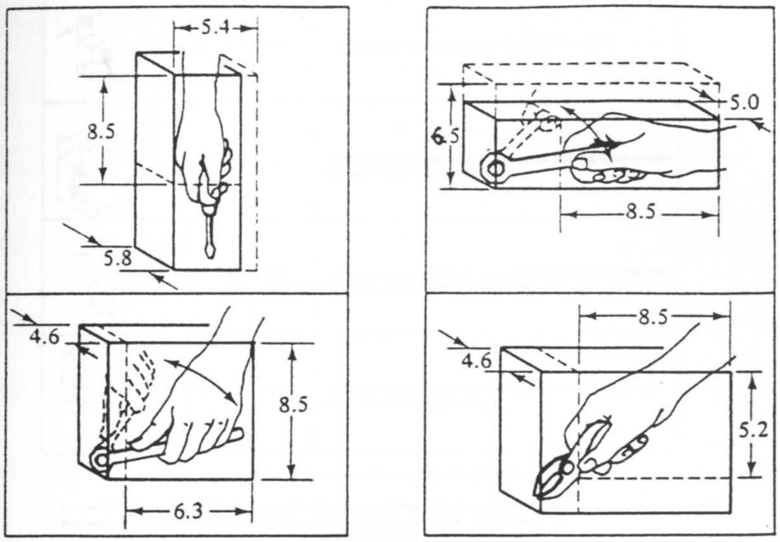


Figure 4.5: Space Required For Using Common Hand Tools [6]

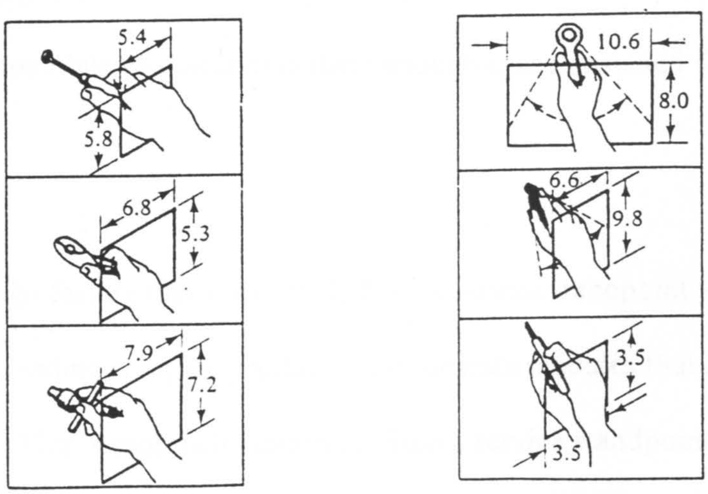
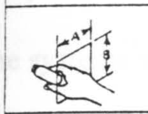
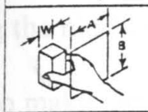
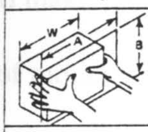
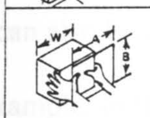
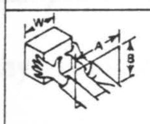


Figure 4.6: Minimum Openings For Using Common Hand Tools [6]

Opening Dimensions	Dimension* (in inches)		Maintenance Task
	A	B	
	4.8	5.0	Grasping small objects (less than 2 1/2" diameter)
	W + 1.75	5.0 †	Grasping large objects (more than 2 1/2" wide)
	W + 3.0	5.0 †	Grasping large objects with two hands, with hands extended through openings up to fingers
	W + 6.0	5.0 †	Grasping large objects with two hands, with hands extended through openings up to wrists
	W + 6.0	5.0 †	Grasping large objects with two hands, with arms extended through openings up to elbows

Minimum Rectangular Openings for Grasping Parts

* The dimensions are extrapolated from data presented in: *Guide to Design of Electronic Equipment for Maintainability*. WADC Technical Report 56-218, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, 1956; and *Anthropometry of One-Handed Maintenance Actions*, Technical Report NAVTRADEVCEN 330-1-3, U. S. Navy Training Device Center, Port Washington, New York, 1960.

† Or sufficient to clear port
(Data Extracted From NAVSHIPS 94324)

Figure 4.7: Minimum Rectangular Openings For Grasping Parts

Automobile manufacturers are frequently criticized for not providing adequate space allowances for optimum accessibility. As an example, consider replacing an oil filter. This is probably one of the most frequently performed maintenance procedures conducted on an automobile, yet seldom is there enough space provided for the necessary tools.

4.2.3 Modularity

Another design feature that is desirable from a service standpoint is modularity. This is achieved by dividing complex products into separate modules that are then assembled together. This is especially important from a service standpoint because only the affected module must be removed and replaced by a spare module when a failure occurs. The defective module can be disassembled and repaired after the parent system has been returned to operation. Modularity will decrease the system downtime and thereby increasing the systems availability. Each module must be able to be diagnosed separately. Utilizing the module approach also reduces the amount of skill necessary for the field technician to make the repair.

Other types of modular design exist besides the sub-system concept mentioned above. Modularity can also be useful in that it often allows for more efficient disassembly of a product. For example, in the printer case study, the logic board is located deep within the assembly hierarchy. However to obtain access to service this component only eight operations have to be performed. After the cover is removed, five wire harnesses are disconnected which allows for the print mechanism module to removed, thereby providing the necessary access to the logic printed circuit board. The entire print mechanism module, which contains the majority of the systems components, can be removed by simply disconnecting four wire harness connections.

4.2.4 Other DFS Considerations

An effective way to reduce warranty and service costs is to design the product to minimize the skills and training needed by maintenance personnel, whether it be the end user or a service technician. In order to achieve the lowest service tier, several other design factors must be considered. The need for special tools and test equipment should be eliminated. Also the number and types of standard tools and test equipment needed to perform the task should be minimized.

Permanent fastening methods such as press fits and spot welding should be avoided when considering serviceability. Other methods for fastening components should be designed to allow for quick and easy disassembly. Snap fits are an efficient method for fastening items together, but they can pose significant problems in disassembly if they are not designed correctly. They should be designed such that they can be released by hand or if a tool is necessary, access holes to the release point should be provided. Figure 4.8 contains illustrations of serviceable snap fit designs. [8]

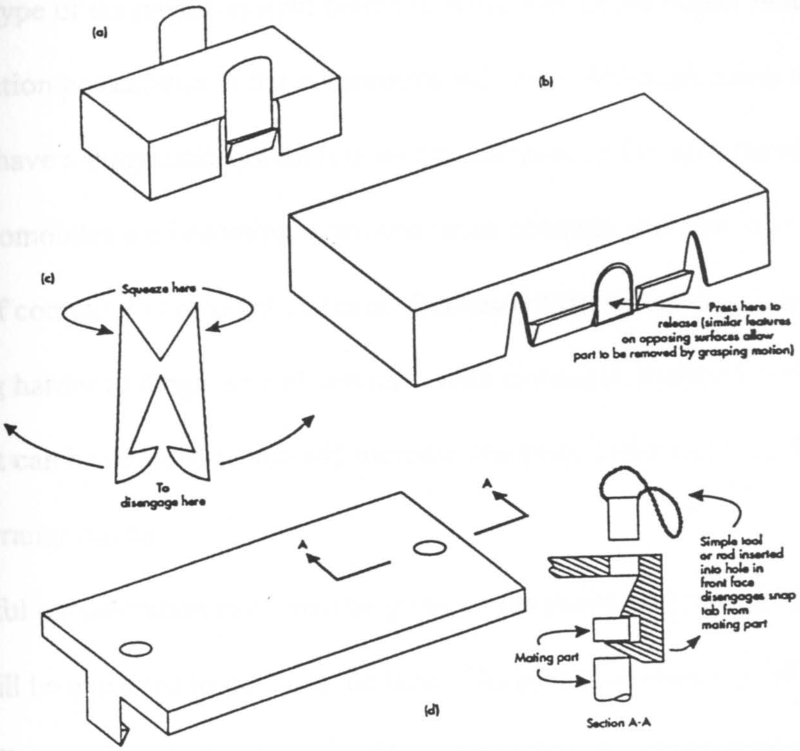


Figure 4.8: Serviceable Snap Fit Designs

Systems should be designed to allow for quick and positive recognition of the failure of high mortality or critical items. The diagnostic capability of a system depends on the complexity of the system. As an example, modern copying machines have a display which identifies failures which can be handled by the operator. Problems such as paper jams are quickly identified complete with the location of the jammed sheet. One quick check allows the operator to clear the machine of paper in a matter of seconds. This type of diagnostic alert should be applied to other more serious failures, so that the repair person can easily identify the failure source and replace or repair it quickly. While this principle will increase the initial purchase cost, it will substantially reduce the warranty and service costs during the life of the product while enhancing customer satisfaction.

This type of diagnostic system seems to work well in the copier industry and has broad application possibilities in the automotive industry. Although many modern automobiles have a diagnostic system it does not compare to the systems contained within copiers. Automobiles are becoming more and more complex with the increasing integration of computer controlled systems. Because of the increasing complexity, failures are becoming harder to diagnose and service. With increased diagnostic capabilities repair time and cost can be reduced which will increase company profits by reducing the money spent on warranty claims.

Careful consideration must also be given to the position in which the service technician will be expected to perform the task. During initial assembly of a product operators will be provided with the assembly in a position for which their efficiency can be maximized. However in service this is not always the case. Technicians will be expected to perform tasks while laying flat on their back, squatting down on their knees or stretched over an obstacle, all of which reduce the efficiency of the service personnel. Placing the operator in these types of postures should be avoided for any task that is conducted on a regular basis. This topic will be further examined in section 4.4.

4.2.6 Summary of DFS Design Considerations

1. Reduce the cost of service parts.
2. Simplify operator and maintenance functions by minimizing the number and the complexity of service tasks.
3. Use modular design techniques.
4. Use self-adjusting mechanisms where possible.
5. Use gear-driven accessories to eliminate belts and pulleys.
6. Maximize design simplicity to reduce the skills and training requirements of service personnel.
7. Design for quick and positive recognition of malfunctions or marginal performance.
8. Design for quick and positive identification of the replaceable defective components or assemblies by utilizing built-in testing and calibration features.
9. Design to minimize the types and number of tools and test equipment (both standard and special) required to perform repair.
10. Design for optimum accessibility to all systems, equipment, and components requiring service, inspection, removal, and replacement.
11. Minimize the probability of damage caused during service tasks by making items sufficiently robust for the anticipated removal and reinsertion process. Also wherever possible separate or isolate delicate items from service locations.

4.3 Progress Function

The logic in the concept of the progress function is that improvement in cost or time occurs as experience is gained. The nature of the function is such that a constant percentage reduction in cost or time is realized with constant percentage increases in total production. The constant percentage changes define a power law equation given by

$$A = a \times x^{b} \tag{4.7}$$

where A = The average cost or time of production

a = The cost or time of the first unit

x = The number of units to be produced

b = The reduction exponent derived from $\dfrac{\log r}{\log f}$ (will always be negative)

and where r = The rate of improvement represented by a decreasing percentage of the original time

f = The factor increase in output (usually in terms of 2)

For example, an improvement rate of 90% means that the average time for the first two times a task is carried out will be 90% of the first time. The average time for the first four repetitions will be 90% of the average time for the first two, and so on. For this improvement rate

$$b = \frac{\log 0.9}{\log 2} = -\ 0.152 \tag{4.8}$$

The concept of constant percentage decreases can also be used to predict the total time or cost (T), Eq. (4.9),and the individual unit time or cost (I), Eq. (4.10). [9,10]

$$T = A \times x = x \times a \times x^{b} = a \times x^{b+1} \tag{4.9}$$

$$I = a \times x^{b+1} - a \times (x-1)^{b+1} \tag{4.10}$$

In the above discussion, the term "learning curve" has been avoided because it implies the rate at which an individual progresses in the performance of a given task with an increased number of repetitions. In contrast, the progress function should be thought of in a much broader sense as being progress accomplished through improved process techniques, tools, and training method as well as the learning associated with repetitions of specific repairs. [11]

Power law progress functions are easily applied to industrial applications because only a relatively few data points are required to generate a relationship.

4.3.1 Maintenance Progress Function

The power law model has been used with some success to determine the time-production relationship for manufacturing operations and for total cost on larger products. An extension of this theory to encompass maintenance operations can be accomplished by making a few adjustments in the concepts in the manufacturing progress function. [12]

1. The manufacturing function describes a system through which all production must flow, the maintenance function characterizes a system through which each unit of product must flow, according to the failure frequency.
2. In the manufacturing function the dependent variable, cost or time, is a production efficiency characteristic, in the maintenance function, the dependent variable is quality, reliability and serviceability characteristics.

Before progress curves can be applied to maintenance functions, it must be shown that maintenance activities do, in fact, follow such curves. Evidence to this effect has been presented by Kniep [11] and Wilson [12]. A typical graph of a progress function applied to maintenance activities is shown in Fig. 4.9. Figure 4.9 assumes a 98% rate of reduction and an initial repair time of one hour.

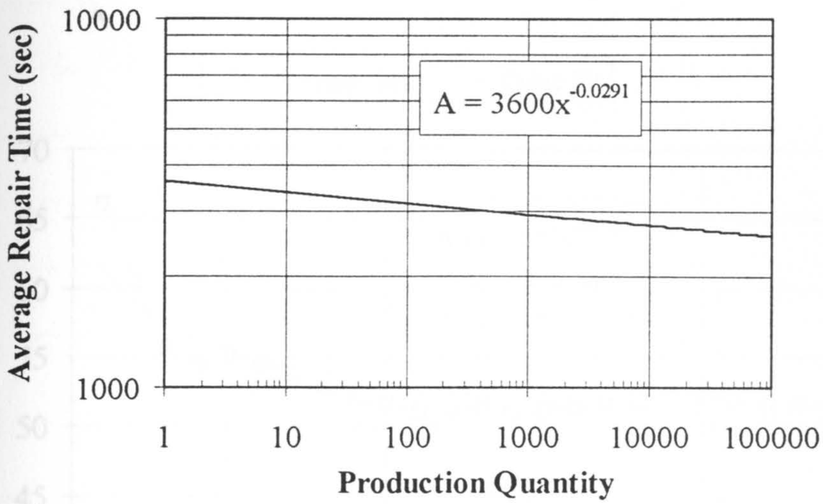


Figure 4.9: Maintenance Progress Function-Log Scale

Applying the progress function to maintenance or service operations may only be valid under certain maintenance organization structures. For example, consider the printer case study, the manufacturer utilizes a single repair location which repairs every similar model. If certain technicians where assigned to each different model, applying the progress function to maintenance operations would be valid. However, if field technicians were used to service the printers, the progress function may not be valid because the time between repairing the same model printer may be so great that little progress may be experienced from performing another repetition. Also, if product failure rates are relatively low and the production quantity is also low then it is likely that little or no improvement in service efficiency will be made from experience

Experiments were undertaken by the author and other IME department students to investigate the application of progress functions to maintenance activities with the results shown in Figs. 4.10 and 4.11.

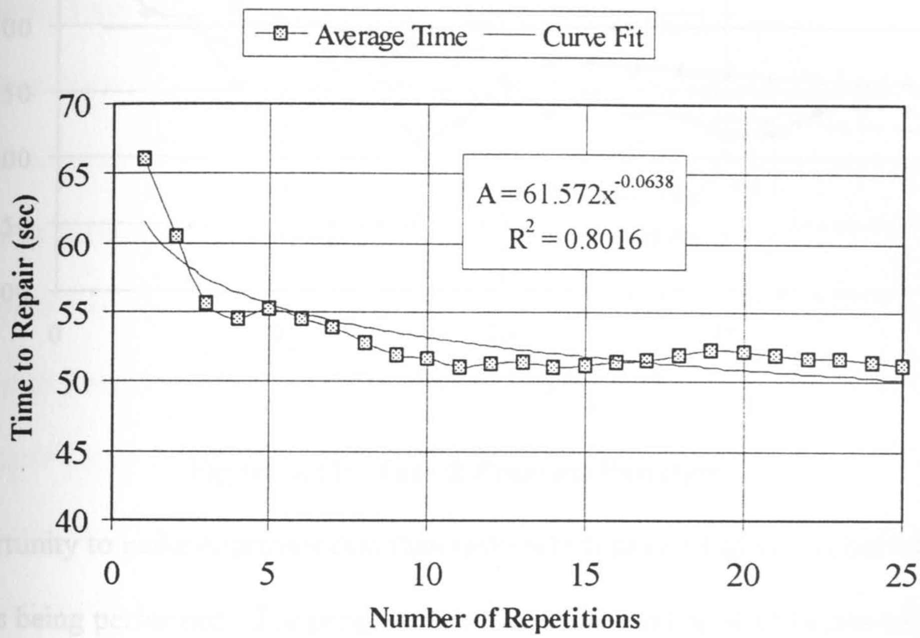


Figure 4.10: Task 1 Progress Function

It can be seen that in both cases that a power law progress relationship exists between the number of repetitions performed and the time to repair the product.

4.3.2 Limitations of the Progress Function

Using the power law form to describe the progress made from experience is faulted in several ways. The most apparent flaw is the inability of the power law equation to account for the leveling off effect after which no additional benefit is gained. The rate at which data levels off appears to be a function of the complexity of the task, or more precisely, the number of operations being performed. Tasks with less operations provide

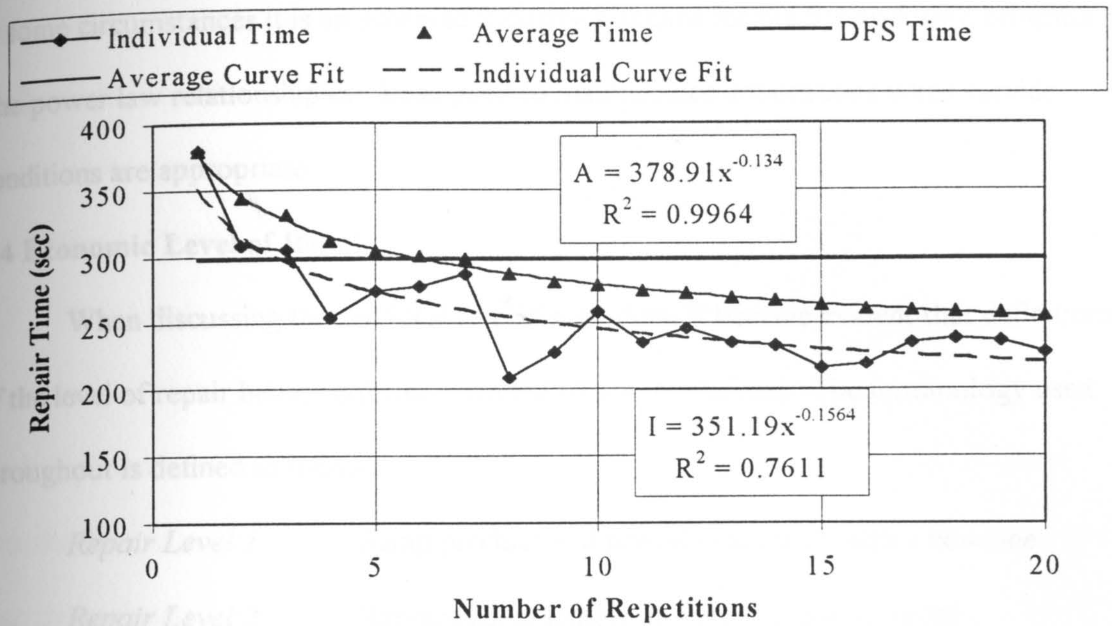


Figure 4.11: Task 2 Progress Function

less opportunity to make improvements than tasks which have a higher number of operations being performed. The progress function shown in Fig. 4.10 begins to level off after ten repetitions at about fifty two seconds. After that point the power law approximation will continue to decrease even though the average time has become approximately constant. If the equation for the power law relationship is extrapolated, the increasing difference between the curves becomes more apparent. Figure 4.11 shows a progress curve for a more complex task. After twenty repetitions the curves for the average time and individual time are still decreasing, hence the leveling off effect observed in Fig. 4.10 is not yet apparent.

Other forms of the progress function have been investigated, but they do not fit the relationship during the initial trials and they are much more difficult to apply than the power law. Even though the power law progress function will provide inaccurate results in some circumstances it is an accepted industry standard for predicting future progress. The power law relationship can be applied to maintenance applications when service conditions are appropriate.

4.4 Economic Level of Repair

When discussing the serviceability of a product, it became evident that definitions of the level of repair being performed needed to also be defined. The terminology used throughout is defined as follows.

Repair Level 1	Scrap product and provide customer with a new one.
Repair Level 2	Replace subassembly in which failure occurred
Repair Level 3	Replace the ultimate failure source(s)

Repair level 1 may seem rather extreme, but currently with many appliances and electronic equipment it is often cheaper to scrap a product and replace it with a new one, than to service it. A distinction between level 2 and level 3 is necessary because component replacement may not always be the most cost effective. For example, if many service operations must be performed to obtain access to the failure source and the cost of the subassembly is low, it may be cheaper to replace the entire subassembly.

The design for service method previously developed at URI can be used during the early design of a new product to determine how it can be serviced most economically. The importance of the development of repair levels becomes evident during discussions with engineers that suggest that data and information from previous product lines is used to determine the appropriate level of serviceability. Therefore, the service tasks that were performed on past products are planned for and repeated on new products without analyzing the consequences of such a decision. A need exists for a repair level index that has been developed to aid in determining how far a service task should proceed before it becomes uneconomical.

4.4.1 Repair Level 1

This level of service is appropriate when it is cheaper to replace the product then to service it or have it serviced. As mentioned before, this practice is very common with small appliances and electronic equipment where the perceived cost to repair is greater than the cost to purchase a replacement. The perceived cost to repair may in fact be less than the replacement cost, but other factors must be included into this equation, one of which maybe the potential for another failure occurring. As a product ages the potential for a failure increases due to the wear of components. However, the traditional bath tub curve model of failures does not apply to all products. For example, in discussion with the printer manufacturer, their printers do not experience a wear out period with an increase in failures. This is attributed to the fact that the design of their product has changed very little over many years and improvements were made in the durability of components. With new designs it is almost impossible to predict, without extensive and expensive testing, which components are susceptible to wear out failures.

When a consumer considers purchasing a replacement product versus repairing a system, the consumer will often pay more than the cost to repair. This occurs for several reasons including but not restricted to; perceived upgrade to 'newer' technology or the idea that the new product is less likely to fail. In the case of automobile insurance, the insurance company will pay on the average up to 75% of the value of a car for repair. [13]

If the cost to repair the damage exceeds 75% of the value of the car, the insurance company will choose to "total" the car and forfeit the extra 25%.

In an attempt to provide a means for making a decision on whether or not to service a product the model from the automobile industry will be adopted. Thus, if Eq. (4.11) is true, then the system will be discarded and replaced, but if it is not true then the product should be serviced.

$$C_{rc} > C_p \times 75\% \tag{4.11}$$

where C_{rc} = the cost to return the system to operating conditions ($)

C_p = the cost of a replacement system ($)

The cost to repair the item, C_{rc}, includes all costs associated with the actual repair of the product, including, labor cost, replacement part cost, shipping cost, logistics cost, and any other cost that can be attributed directly to the repair.

The cost of a replacement system, C_p, is the cost incurred if the decision is made to replacement malfunctioning system with a similar product . However, the replacement cost may not be the cost of a new system. Because every product depreciates with age, the replacement cost is therefore the value of the product at the time of the failure occurring. For example, the cost of the same automobile will be considerably less after several years of use than it was when it was first purchased. Hence, the replacement cost is not the cost to buy a "new" automobile, but the cost to replace the automobile with the same exact automobile. Although an automobile is an extreme case, every product depreciates in value with age to some degree.

4.4.2 Repair Level 2

Repair level 2 represents the point at which the subassembly containing the failure source is replaced. It may often be cheaper to replace the subassembly and avoid the additional costs associated with proceeding further with the disassembly of the subassembly. Equation (4.12) is used to obtain a value for the assembly/subassembly replacement index, I_s.

$$I_s = \frac{C_f}{C_{sub} + T_{sub} \times L} \tag{4.12}$$

where C_f = the cost of failure source(s) (\$)

C_{sub} = the cost of replaced assembly/subassembly (\$)

T_{sub} = the time to replace assembly/subassembly (seconds)

L = the labor rate (\$ / second)

4.4.3 Repair Level 3

Repair level 3 is the lowest level of service that can be performed because it involves the replacement of the actual component that caused the failure of the system. Calculating the assembly/subassembly index given in Eq.(4.12) is purely an academic exercise without being able to compare it to the repair index for the failure source. Keeping in mind that the identical service procedure has been followed up to the point that the subassembly begins to be disassembled, the equation for the failure source replacement index I_f is given in Eq. (4.13).

$$I_f = \frac{C_f}{C_f + C_d + C_t + T_f \times L} \tag{4.13}$$

where C_d = Value of discard items ($) (items such as seals that must be replaced simply because they have been disassembled)

C_t = Cost of special tools or equipment required ($)

T_f = the time to replace failure source (seconds)

If there is a risk of damaging a component during the replacement of the failure source then this cost must also be incorporated into Eq. (4.13). If replacing the failure source may damage parts $S_1, S_2, S_3, \cdots, S_n$ of value $C_1, C_2, C_3, \cdots, C_n$ with the probability of damage $P_1, P_2, P_3, \cdots, P_n$ then the expected cost of damaged parts, C_{dp}, can be given as

$$C_{dp} = C_1 \times P_1 + C_2 \times P_2 + C_3 \times P_3 + \cdots + C_n \times P_n \tag{4.14}$$

Now inserting C_{dp} into Eq. (4.13) yields

$$I_f = \frac{C_f}{C_f + C_d + C_t + C_{dp} + T_f \times L} \tag{4.15}$$

After calculating both I_s and I_f, the appropriate level of service can be determined. If I_f is greater than I_s, then it will be more economical to replace the failure source. However if I_s is greater than I_f, then the subassembly containing the failure source should be replaced. The same calculation can be performed by simply adding up the associated costs of servicing whether it be repair level 1 or 2. However, the indices were developed to aid the designer in identifying the costs associated with each level so that the calculations would accurately predict the most economical solution.

4.4 Worker Position Modifier

The current DFS database does not distinguish between different operator positions. Operations performed in uncomfortable positions or positions where the operators movement is restricted should intuitively require a longer time to perform than operations performed under ideal conditions. Priest [14], has developed time penalties to adjust assembly time to account for various operator positions and the values for these modifiers are given in Table 4.1.

Table 4.1: Modifier for Worker Position

Worker Position	Modifier
Stand on ladder	1.1
Kneel on one or both knees	1.2
Stooping from a standing position	1.2
Stretch over obstacle	1.2
Lie on back	1.2
Squat on knees	1.3
Lie on side	1.5

The author conducted experiments in order to verify that the modifiers could be applied to the current DFS time database values. It was assumed that the DFS time databases offered a fairly accurate time estimate for any given operation or task. At first the experiments were designed such that the time for the entire task, carried out in an uncomfortable position, would be compared to the DFS predicted values. However, upon review of the videotaped procedures, it was determined that while the times obtained from the DFS database were indeed significantly less than the actual times, they did not agree with the modifiers suggested by Priest. It was then decided that the difference was caused by multiplying the item acquisition, item set-aside, tool acquisition and tool set-aside times by the multiplier factor. When reviewing the videotape, it appeared that these times were not adversely effected by the position of the operator. Hence, the next series of experiments focused specifically on the time to perform the item removal and insertion operations. It was assumed that if three of the multipliers were proven correct, then all seven could be assumed valid.

The experiment developed to test for the existence of the position multipliers consisted of six screw securing and unsecuring operations. Six successive operations where chosen to try and reduce the amount of variation between trials. The three positions that the experiments were conducted in were lying on side, kneeling on both knees, and stretching over an obstacle. The data collected was subjected to a student's t test in order to test the hypothesis that the means of the data sets were equal to the

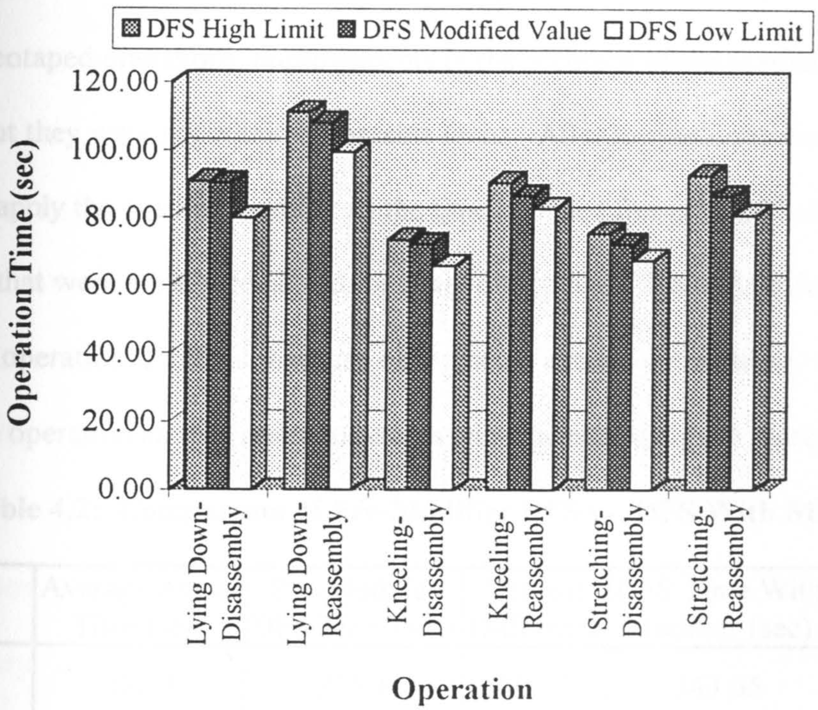


Figure 4.12: Actual Time vs. Limits @ 95% Confidence

predicted DFS time values multiplied by the position multiplier. In all three circumstances the hypothesis that the means were equal to the DFS modified time was proven true at a 95% confidence interval for both the disassembly and reassembly tasks; see Fig. 4.12. The data obtained from the experiments and the results of the statistical analysis are contained in Appendix A.

The next step was to determine how the penalties should be applied to the times obtained from the DFS databases. Currently the databases contain penalties for many difficulties associated with performing service operations. How the position penalty should be applied when other penalties were also applied was unknown and needed to be determined. First, it was thought that the multiplier would be applied to the unpenalized time to perform an operation and then have the other associated penalties applied to the position adjusted time. However, upon comparing DFS times to the times obtained from several videotaped operations, improvements in the accuracy of the predicted times occurred but they were not within acceptable limits. After further consideration, it was decided to apply the position modifier to the time obtained from the DFS database for operations that were already penalized for other difficulties. The logic behind the decision is that if an operation is difficult because of restricted access, for example, then the basic time for the operation and the restricted-access time penalty will both increase because of

Table 4.2: Comparison of Pre-Modifier DFS vs. DFS With Modifier

Task	Average Actual Time (sec)	Pre-Modifier DFS Time (sec)	Percent Difference	DFS Time With Modifier (sec)	Percent Difference
Drain Motor	322.8	225.1	30.27	343.65	6.46
Defrost Timer	488.2	369.9	24.23	518.65	6.24
Compressor	597.1	443.9	25.66	626.15	4.87
Compressor Fan Motor	689.45	545.6	20.86	746.20	8.23

the operator's uncomfortable position. This idea was then applied to the DFS times for the videotaped operations. Each operation was performed twice to gain familiarity with the procedure, then five additional repetitions were used to obtain the average times to perform the operations. The results of the analysis are contained in Table 4.2, with the supporting data contained in Appendix A. Therefore, it is intended that the position modifiers obtained will be applied to the time given by the DFS database for an operation with other difficulties already included. For example, consider Eq. (4.16).

$$T_t = T_o \times P_m \tag{4.16}$$

where T_t = Total time for 1 repetition of the operation

T_o = DFS time to perform 1 repetition with appropriate difficulty penalties

P_m = Appropriate position modifier from Table 4.1

It was also assumed that because the literature on the subject did not have different modifiers for different operations, that one penalty would apply to all types of operations encountered during maintenance operations. This assumption is backed up by the results obtained in Table 4.2, where actual times to perform service tasks are compared with the adjusted times obtained from the DFS database. Every task examined involved many different types of operations and the results are within acceptable limits of error.

4.5 Summary

In this chapter the topic of service efficiency was revisited and its relationship to importance rank was discussed. Several design guidelines to improve upon the serviceability of a product were introduced and the effect of the progress function on maintenance activities was explained. Often the position in which the service technician is forced to perform an operation will negatively impact upon the service efficiency of the task. The current DFS database fails to adjust the time to perform an operation based on the position of the operator. Therefore, a position modifier found in the literature was tested for validity. Also, the factors responsible for determining the economic level of repair have been identified.

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Chapter 5: Case Studies

Several products supplied from industry were used to test and validate procedures and methodologies developed in this project and other previous research in DFS. The first step in completing a service strategy for a product was to perform importance analyses as outlined in Chapter 3. Next, those tasks identified as important were analyzed using the current DFS methodology developed by Subramani and Whyland.[1,2] The service tasks were then carried out by the author to ensure that the difficulties associated with performing the service task were correctly captured in the analysis. These tasks were also videotaped to provide validation for the time databases used. Appendix B contains the DFS results for all the case studies performed for this project.

5.1 Database Validation

Before the data obtained from the DFS software could be used to evaluate the serviceability of a product, it was necessary to validate the databases utilized by the software. The tasks performed on the printer and several tasks performed on a washing machine were used. A careful understanding of each task was achieved by performing each task two times and then five more repetitions were videotaped to obtain the necessary times. After this was completed a DFS analysis was performed and the times obtained from the databases where then compared to the actual times. Conditions of the actual service where duplicated in the software analysis. For example, hand tools where used to service the items, so the hand tool option was chosen in the software. Only operations that were performed during the service procedure were compared in the software. For instance, when removing the cover of the printer, a special fixture is used to release the snap fits. However, since the fixture was not available, the time for removing the cover was obtained from the DFS database and added to the actual time for the service task.

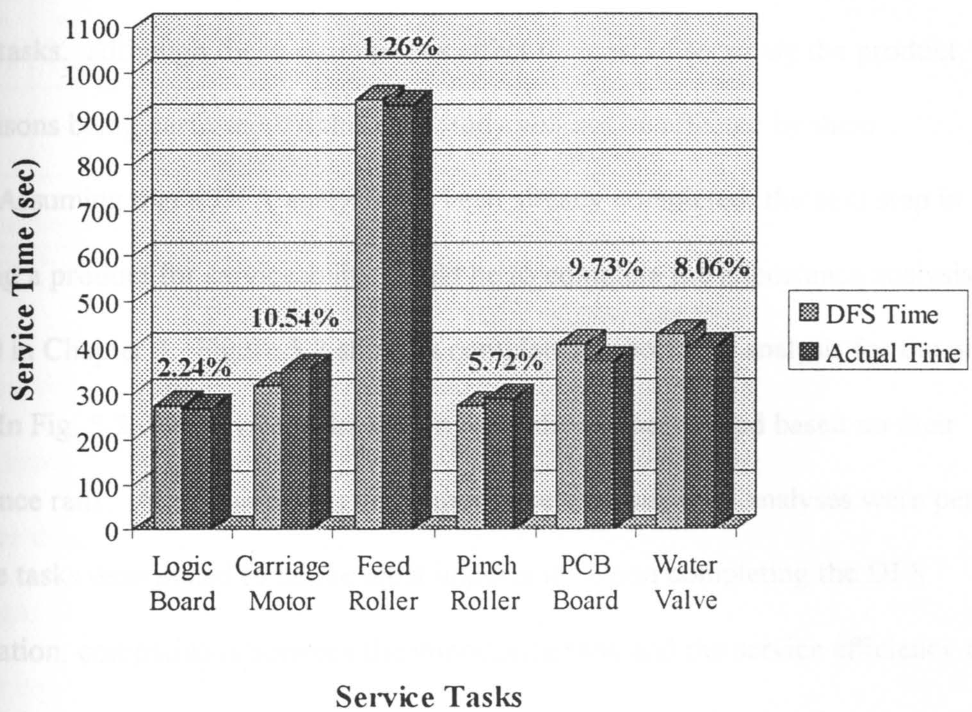

Figure 5.1: Database Validation-Actual Time vs. DFS Time

As shown by Fig. 5.1, the difference between the DFS predicted times and the actual times to perform the operations are within acceptable limits of accuracy. In the worst instance, there is a ten percent difference between the predicted and actual carriage motor service tasks.

5.2 Printer Case Study

Analyses contained within this report focus only on replacing the actual faulty components of the mechanism. It was not known whether replacement of any parts should be done as preventive service, so it was assumed that no "non-faulty" parts were replaced during the service operations. The extent of cleaning performed on the printer during service was also unknown, so cleaning operations were omitted from the printer service tasks. Although these assumptions affect the cost of servicing the product, the comparisons being performed in this case study will not be affected by them.

Assuming that a DFA analysis has been already completed, the next step in analyzing a product for serviceability would be to complete the importance analysis outlined in Chapter 3. Figure 5.2 shows a completed importance analysis for the printer.

In Fig. 5.2, the service tasks shown have already been listed based on their importance rank. After completing the importance analysis, DFS analyses were performed on those tasks determined to be the most important. Upon completing the DFS investigation, comparisons between the importance rank and the service efficiency can be made. It is assumed that those tasks with a lower efficiency value than importance rank should be considered for design improvements to increase the serviceability of the procedure as recommended by Table 3.3. With this assumption, it appears from Fig. 5.3 that the only tasks on the printer that need improvement are the feed roller and the roller clutch procedures. Again, remembering that the roller clutch is a component on the feed roller, improving the serviceability of feed roller task will improve both procedures.

Entry	Name	Id. Number	MTTF	Function of System	IA #
System being analyzed	Color Printer	—	0.0141	To produce color print outs	1
Next higher assembly	—	—	—	—	—

Failure Source	FF (per/yr)	MTTF	Freq. Rank	Function of Failure Source	Potential Failure Mode	Effect of Failure	Con. Rank	Potential Cause of Failure	Import. Rank	Service Eff. (%)
Print Mechanism-Paper Out	50	0.02	10	Feed paper to print cartridge	Paper runs out	Printer will not operate	6	Paper supply diminished	60	58.8
Print Mechanism-Paper Jam	12	0.0833	9	Feed paper to print cartridge	Paper jam	Printer will not operate	6	Multiple pieces of paper fed together	54	71.4
Color Ink Cartridge	3	0.3333	8	To provide color ink to paper	Ink runs out	Print quality will deteriorate	5	Cartridge not sealed properly	40	58.8
Black Ink Cartridge	6	0.1667	8	To provide black ink to paper	Ink runs out	Print quality will deteriorate	5	Cartridge not sealed properly	40	58.8
Logic Board	0.015	66.667	4	To control the operation of the printer	Printer will not function correctly	Printer will not work when needed	6	Poor quality component or ESD	24	23
Feed Roller	0.0065	153.85	3	Feed paper to the print cartridge	Clutch breaks	Paper will not feed correctly	6	Over-stressed clutch mechanism	18	1.91
Roller Clutch	0.0065	153.85	3	Facilitate feeding of paper	Mechanism fails	Paper will not feed correctly	6	Over-stressed component	18	1.75
Pinch Rollers	0.02	50	4	Facilitate paper feeding	Rollers wear out	Paper will not feed correctly/not severe	4	Over-stressed or poor quality	16	15.6
Carriage Motor	0.002	500	2	Move print carriage across paper	Motor fails to operate	Printer will not print	6	poor quality	12	11.4

MTTF - Mean time to failure (1/failure rate)
FF - Failure frequency failures per year
Importance Rank = Frequency rank x Consequence rank

Figure 5.2: Importance Analysis for Printer

However, because the importance rank of the tasks are so low, only design changes that will not increase the manufacturing costs of the product would be acceptable. Figure 5.4 compares the service task importance to the service efficiencies for the original design and a redesign. Although a modest improvement in the service efficiency exists, the index still does not equal the importance rank. The real improvement in warranty costs for the redesigned printer is the reduction in shipping and handling costs created by the elimination of the need for special alignment equipment. The service tasks could now be performed at a lower service tier resulting in lower transportation costs.

Printer service tasks which should be easy to perform, such as adding paper or replacing an ink cartridge, because they have a high importance ranks also have a equally high or higher service efficiency index. Therefore, the procedures used to correct the these failures can be considered adequately designed for service.

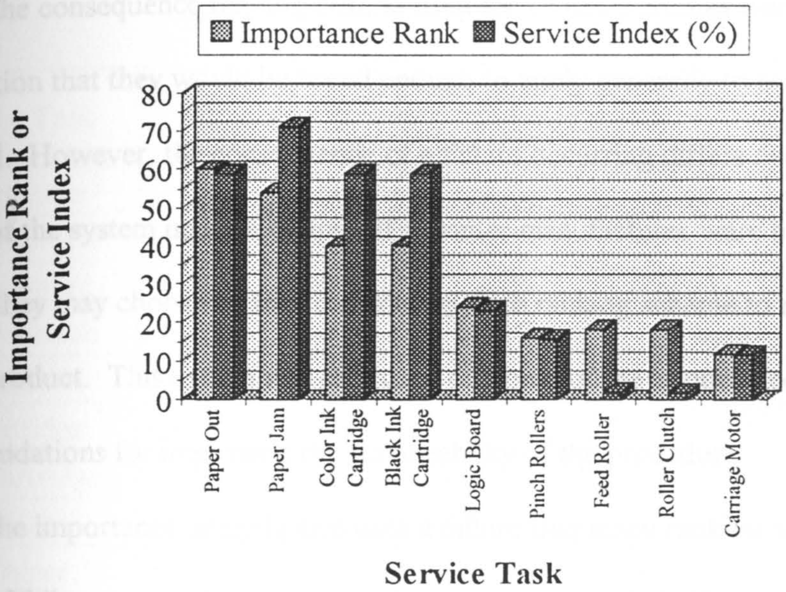

Figure 5.3: Importance Rank vs. Service Index-Printer

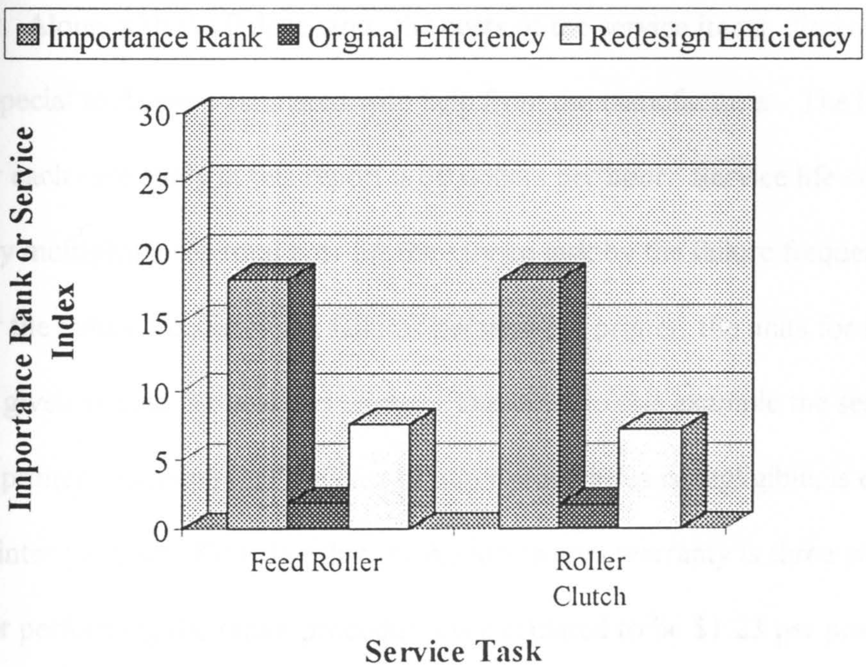

Figure 5.4: Importance Rank vs. Service Indices

The consequence ranking criteria used for all cases studies were developed with the intention that they would be broad enough to apply generally to each product examined. However, the consequence of a failure occurring differs depending on the mission of the system under scrutiny. If a printer manufacturer were to use the importance scheme, they may choose to alter the consequence ranking scheme to more suitably apply to their product. This in turn will effect the outcome of the importance analysis and the recommendations for improving the serviceability of the procedure.

The importance analysis also uses a failure frequency ranking scheme based on the amount of failures occurring per year. A more representative scheme may be in terms of the length of the warranty period or the expected life of the product.

The results obtained from performing the DFS analysis on the printer are presented in Table 5.1. Along with the failure rates, the costs of the service items, discard/new items, and special tools were estimated with help from the manufacturer. The labor rate assumed for each case study in this report is 30 dollars per hour. Service life cost is calculated by multiplying the total cost for the service task by the failure frequency. Since the units for the failure frequency are failures per year per printer, the units for the service life cost are given as cost per year per printer. Therefore in this example the service life cost for the printer, assuming that the cost of other procedures is negligible, is equal to 41 cents per printer per year. Knowing that the manufacturers warranty is three years, the total cost for performing the repair procedures is calculated to be $1.23 per printer.

Table 5.1: Printer Service Cost Summary

Service Task	Labor ($)	Service Items ($)	Discard/New ($)	Special Tool ($)	Total ($)	Service Life ($)
Pinch Roller	2.40	0.30	0.00	0.00	2.70	0.0081
Carriage Motor	2.64	5.00	0.00	0.00	7.64	0.0115
Logic Board	2.28	50.00	0.00	0.00	52.28	0.267
Roller Clutch	8.58	1.00	1.00	0.95	11.53	0.0484
Feed Roller	7.85	10.00	0.00	0.00	17.85	0.075
Ink Cartridge [1]	0.25	4.00	0.00	0.00	4.25	25.5
Color Cartridge [1]	0.25	8.00	0.00	0.00	8.25	24.75
Paper Jam [1]	0.21	0.00	0.00	0.00	0.21	2.52
Add Paper [1]	0.13	0.00	0.00	0.00	0.13	6.5
Total	24.59	78.3	1.00	0.95	104.84	59.68

[1] Tasks likely performed by end user.

Now that the importance analysis is complete, the next phase of the service strategy can be performed. Figure 5.5 is a worksheet developed to aide in the completion of the service task classification as outlined in Chapter 3. The columns in Fig. 5.5 correspond with responses that are obtained from performing the analyses outlined in Figs. 3.2, 3.3 and 3.4. Upon examination of the service tasks for the printer, it can be seen in Fig. 5.5 that all of the service tasks will be performed in an corrective fashion. The first two tasks, which involve replacement of paper and the removal of a paper jam, are performed without removing any components from the assembly and the tasks will be performed by the end-user. Considering replacement of the print cartridges, which occurs when the ink runs out, the cartridges are discarded because repair is impossible and the procedure will be conducted by the end-user. The logic board will also be discarded upon failure, but the replacement of this component demands the skill of a trained technician.

Entry	Name	Id. Number	Function of System
System being analyzed	Color Printer	—	To produce color print outs
Next higher assembly	—	—	—

Task	Importance Rank	Service Classification		Corrective Categories						Service Organization		
		Preventive Service	Corrective Service	AAC	RIP	DSCD	SCRN	REP	NL	First Tier	Second Tier	Third Tier
Print Mechanism-Paper Out	60		X		X					X		
Print Mechanism-Paper Jam	54		X		X					X		
Color Ink Cartridge	40		X			X				X		
Black Ink Cartridge	40		X			X				X		
Logic Board	24		X			X					X	
Pinch Rollers	16		X			X					X	
Feed Roller	15		X				X					X
Roller Clutch	15		X			X						X
Carriage Motor	12		X			X					X	

Figure 5.5: Maintenance Organization Worksheet-Printer

Replacement of the feed roller requires special equipment which is too expensive for local repair facilities. Hence, it must be repaired using a central repair location. If the service procedure could be changed such that the alignment between the roller and ink cartridges was not disturbed during service, then repair could be conducted at the second tier. Since at least one task must be performed at the third tier, it seems likely that all of the service tasks not performed by the end-user will be performed at the third tier.

Designing for the end-user to repair is the most economical strategy, but for some products this may never be feasible. Using a third tier system is the most uneconomical approach to an service organization because often the transportation costs associated with it exceed the cost of actually repairing the product.

Lastly, the overall service efficiency index can be calculated by using Eq. (4.6). The service efficiency of the printer is calculated to be approximately 61%.

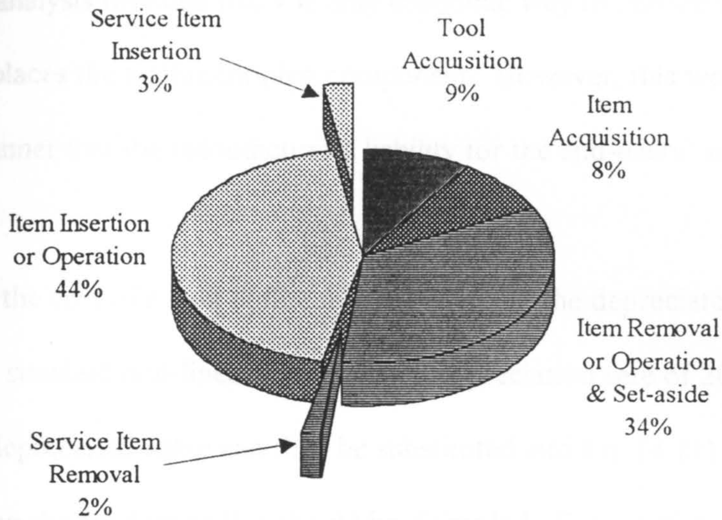

Figure 5.6: Total Time Summary For Printer

5.3 Coffee Maker Case Study

With increased consumer interest in "green" products, a decision was made to examine a product for serviceability that is considered non-repairable and is discarded when a failure occurs. In 1993 it was estimated that in approximately 13 million drip coffee makers were replaced in the US alone [3] contributing approximately 23.4 million kilograms of waste to landfills. Increasing the serviceability of a product will extend the useful life of the product and thereby reduce the amount of material placed in landfills. However, extending the life of such a product is currently not in the manufacturers best interest. If the useful life is extended, the manufacturer must forego the benefit gained from the consumer purchasing a new product and generating revenue. Current market infrastructures offer little motivation for a manufacturer of such a product to design the system to be serviced. In fact, the appliance examined used several threaded fasteners that required a special tool in order to remove them.

The DFS analysis revealed that the only economic way to service such a product is if the end-user replaces the malfunctioning component. However, this would have to be done in such a manner that the manufacturers liability for the end-users' safety is eliminated.

Assuming the cost of a new coffee maker is \$30.00, the depreciated value is calculated using a standard non-linear model with a depreciation rate of 20% per year for four years. This depreciated value can then be substituted into Eq. (4.11) to determine if it is worth repairing the product or if it should be discarded. Substituting the values into Eq. (4.11) yields:

$$C_{rc} > \$9.49 \times 75\% = \$7.1 \tag{5.1}$$

Hence, if the cost to return the product to operating condition exceeds \$7.13, then the product should be replaced and not repaired. Assuming the printed circuit board fails, the cost to repair is estimated by the DFS methodology to be \$8.25, which includes labor, discard/new and service part costs. Now if the service procedure was carried out by the end-user the labor cost is eliminated. The end-user would only have to purchase the replacement part and the discard/new parts, which was estimated to be approximately \$5.20. It may seem to be an unreasonably high estimation for a simple printed circuit board, but often service parts cost significantly more than the manufacturers purchase cost.

Examining the importance ranking of the serviceability of the coffee maker reveals that it may be necessary to consider servicing the appliance. Assuming that the MTTF for the coffee maker is four years [3], a failure frequency rank of 7, and that any failure that occurs causes a total loss of operating capability, a consequence rank of 6, then this gives an importance rank equal to 42. Referring to Table 3.3, the service quality category recommends that design changes to improve serviceability be made. The service efficiency for the current design is calculated to be 7.6%. Obviously the service efficiency of the coffee maker needs to be improved dramatically if it is to equal the importance rank.

The current service procedure involves removing and replacing 13 parts and performing 4 separate disassembly and reassembly operations. However, the product could be designed such that the service task would only involve removing and replacing 7 parts, thereby increasing the service efficiency to 33%. Some of the serviceability design improvements may cause a slight increase in the initial manufacture cost, but according to the importance rank this is acceptable.

The author realizes that it is unlikely that a coffee maker or any other similar inexpensive appliance will be designed for efficient serviceability. Currently there is very little motivation for the products' manufacturer to incorporate design for service principles into the design. However, if forthcoming governmental legislation imposes tariffs on dumping such appliances, then incentive for using DFS may be artificially created. Also, there are many different manufacturers of such appliances who in turn market many different models. The only way to develop a truly serviceable product would be to make standard replacement components readily available to the end-user or service technician.

Clearly in this case there seems to be a disagreement between the recommended quality of service and the actual non-repair of the product because of the inexpensive purchase cost of the product. It seems that the importance scheme may not correctly apply to products that are considered non-repairable.

5.4 Refrigerator Case Study

A full size refrigerator was also used as a case study to test the strategy developed in this project. The importance analysis was performed on service items identified by the manufacturer and some tasks that were added by the author to supplement the analysis. For example, the manufacturer was only interested in corrective maintenance procedures that they would be responsible for under warranty. The author added the replacement of the light bulbs and the task dealing with emptying the water tray. Figure 5.7 shows the completed importance analysis for the refrigerator assembly. The actual failure frequencies and service part costs are not presented here due to confidentiality agreements between the author and the manufacturer. However, the conclusions drawn about the serviceability of the product will not be effected.

Figure 5.8 compares the importance ranking to the service task efficiency index obtained from the DFS analysis. The time needed to remove food from either the refrigerator compartment or the freezer compartment was neglected and will not be reflected in the service efficiency index. It was assumed that for any failure, the removal of food that it would have to had been done by the owner to avoid spoilage of the food in the system. From the importance analysis worksheet, it can be seen that because each task has a low frequency rank or a low consequence rank, that the resulting importance rank for each task is relatively low. Even though Fig. 5.8 shows some discrepancies between

Entry		Name			Id. Number	MTTF	Function of System			IA #
System being analyzed		Refrigerator			—	0.205	To keep products from spoiling by cooling them			1
Next higher assembly		—			—	—	—			—
Failure Source	**FF (per/yr)**	**MTTF**	**Freq. Rank**	**Function of Failure Source**	**Potential Failure Mode**	**Effect of Failure**	**Con. Rank**	**Potential Cause of Failure**	**Import. Rank**	**Service Eff. (%)**
Refrig. Light Bulbs	0.571	1.75	8	Illuminate refrig. compartment	Filament burns out	Can not see in refrig.	2	Useful life exceeded	16	12.85
Freezer Light Bulb	0.286	3.5	7	Illuminate freezer compartment	Filament burns out	Can not see in freezer	2	Useful life exceeded	14	7.80
Compressor	0.0021	476.19	2	Cool freon	Freon not cooled	System cannot cool	7	Item wears out	14	2.94
Refrig Door	0.0048	208.33	3	Keep cold air in refrig	Improper insulating properties	Refrig. works harder to maintain temp.	4	Poor assembly quality	12	1.91
Refrig Thermostat	0.0019	526.32	2	Control refrig temperature	Cannot measure temp correctly	Temp to warm or cold	5	Poor quality	10	4.47
Compressor Motor Fan	0.0008	1250	1	Keep compressor cool	Motor burns out	Temp of compressor to high	8	Poor quality	8	4.37
Freezer Door	0.0025	400	2	Keep cold air in freezer	Improper insulating properties	Freezer works harder to maintain temp.	4	Poor assembly quality	8	3.37
Empty Water Tray	4	0.250	8	Collect water from freezer	Water collects in tray	Water begins to become odorous	1	Freezer defrost cycle	8	5.50
Freezer Thermostat	0.001	1000	1	Control freezer temperature	Temperature not maintained	Freezer will not work	5	Poor quality	5	8.24
Freezer Motor Fan	0.0008	1250	1	To circulate cold air	Motor burns out	Temp rises above acceptable limits	5	Poor quality	5	6.89
Defrost Timer	0.0012	833.33	1	Control defrost cycle	Timer burns out	System will not defrost	4	Component wears out	4	4.53
Lower Door Hinge	0.0005	2000	1	Support door and allow for motion	Hinge will not support weight	Door does not open correctly	4	Over stressed	4	1.26

MTTF - Mean time to failure (1/failure rate)
FF - Failure frequency failures per year
Importance Rank = Frequency rank x Consequence rank

Figure 5.7: Importance Analysis-Refrigerator

the efficiency index and the importance rank, changes in design for ease of service that will increase the manufacturing cost are not recommended. However, minor changes that improve serviceability without compromising manufacurability are deemed to be necessary. For example, in the freezer light bulb replacement procedure, the lens cover could not be removed so the entire subassembly had to be removed to gain access to the bulb. Therefore, if the lens cover was designed such that it could be removed without causing damage to it, then the service efficiency would significantly increase. Table 5.2 lists the results from the DFS analysis performed on the refrigerator. The overall service efficiency for the product is calculated to be approximately 6.5% using Eq. (4.6).

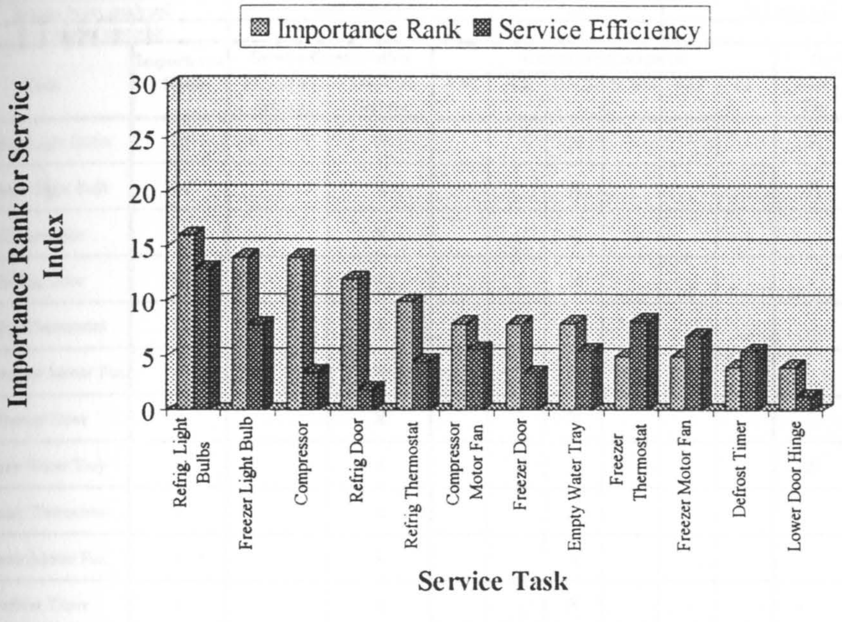

Figure 5.8: Importance Rank vs. Service Index-Refrigerator

Table 5.2: Refrigerator Service Cost Summary

Service Task	Labor ($)	Service Items ($)	Discard/New ($)	Total ($)	Service Life ($)
Comp. Fan Motor	6.86	9.10	0.00	15.96	0.03
Compressor	7.56	60.00	35.00	102.56	0.43
Defrost Timer	4.96	8.00	0.00	12.96	0.03
Refrig. Thermostat	5.11	8.80	0.00	13.91	0.05
Thermostat Fr.	2.73	9.80	0.20	12.73	0.03
Freezer Fan Motor	4.35	9.10	0.00	13.45	0.02
Lower Door Hinge	5.94	3.00	0.00	8.94	0.01
Refrigerator Door	3.93	40.00	0.00	43.93	0.42
Freezer Door	2.23	20.00	0.00	22.23	0.11
Freezer Bulb [1]	1.92	0.50	0.00	2.42	1.38
Refrigerator Bulb [1]	1.17	1.00	0.00	2.17	2.48
Water Tray [1]	1.53	0.00	0.00	1.36	5.44
Total	48.29	169.3	35.2	252.62	10.43

[1] Tasks likely performed by end-user

Entry	Name	Id. Number	Function of System
System being analyzed	Refrigerator	—	To keep food from spoiling
Next higher assembly	—	—	—

Task	Importance Rank	Service Classification		Corrective Categories						Service Organization		
		Preventive Service	Corrective Service	AAC	RIP	DSCD	SCRN	REP	NL	First Tier	Second Tier	Third Tier
Refrig. Light Bulbs	16		X			X				X		
Freezer Light Bulb	14		X			X				X		
Compressor	14		X			X					X	
Refrig Door	12		X			X					X	
Refrig Thermostat	10		X			X					X	
Compressor Motor Fan	8		X			X					X	
Freezer Door	8		X			X					X	
Empty Water Tray	8		X	X						X		
Freezer Thermostat	5		X			X					X	
Freezer Motor Fan	5		X			X					X	
Defrost Timer	4		X			X					X	
Lower Door Hinge	4		X			X					X	

Figure 5.9: Maintenance Organization Worksheet-Refrigerator

5.5 Washing Machine Case Study

Investigation of the serviceability of a large capacity washing machine was also undertaken to demonstrate the "complete" DFS methodology. As before, the product manufacturer suggested several service procedures to be investigated. The actual failure frequencies and associated costs where not used in this analysis but the conclusions made about the serviceability of the product will not be effected. Figure 5.10 contains the importance analysis for the washing machine and Fig. 5.11 compares the service efficiency to the importance rank.

Tasks which should be easy to perform because of high frequency rank and/or high consequence rank, such as cleaning the lint filter, have a high service efficiency index. The other tasks have low importance ranks because of low failure frequencies. This is another example where the general consequence ranking scheme developed may be inadequate for this product. The highest consequence of failure for this washing machine may only be an 8 in the current scheme which would be "a total loss of operating capability causing major disruption to important activity or causes major damage to other items." Therefore

Entry		Name		Id. Number		MTTF	Function of System			IA #
System being analyzed		Washing Machine		—		20.33	To Clean Clothes			1
Next higher assembly		—		—		—	—			—
Failure Source	**FF (per/yr)**	**MTTF**	**Freq. Rank**	**Function of Failure Source**	**Potential Failure Mode**	**Effect of Failure**	**Con. Rank**	**Potential Cause of Failure**	**Import. Rank**	**Service Eff. (%)**
PCB Subassembly	0.0048	208.33	3	Control operation of washer	PCB board malfunctions	Washer stops working	6	Poor quality of PCB board	18	9.09
Filter net	24	0.0417	9	Filter out foreign objects from water	Filter becomes full	Water does not flow properly	2	Foreign objects in water	18	65.93
Shaft Subassembly	0.0024	416.67	2	Turn spin basket	Shaft	Spin basket will not turn	6	Assembled incorrectly	12	1.86
Drain Motor	0.0024	416.67	2	Pulls bellows back to allow water to drain	Gear in motor fails	Water will not drain from tub	5	Poor quality of gear	10	8.67
Power Switch Sub	0.0012	833.33	1	Turn washer on/off	Switch malfunctions	Washer will not turn on	6	Poor quality	6	10.80
Motor Subassembly	0.0004	2500	1	To turn spin basket	Motor shorts out	Washer stops working	6	Poor quality of motor	6	5.45
Fuse	0.0004	2500	1	Protect system from electrical spikes	Fuse element fails	Will no longer function	6	Electrical power surge in the system	6	3.56
Power Cord	0.0004	2500	1	Provide power to system	Electrical system becomes grounded	Will no longer function	6	Wires become grounded or damaged	6	5.02
Drain Valve Bellows	0.0008	1250	1	Allows water to drain from tub	Rubber bellow rips	Water does not drain properly	5	Rubber becomes contaminated	5	5.14
Pressure Sensor	0.0004	2500	1	Detect water pressure	Sensor stops working	Washer malfunctions but still operates	4	Sensor assembled incorrectly	4	10.97
Water Valve	0.0002	5000	1	Controls water flow	Valve sticks	Water flow disrupted	4	Valve wears out	4	8.38

MTTF - Mean time to failure (1/failure rate)
FF - Failure frequency failures per year
Importance Rank = Frequency rank x Consequence rank

Figure 5.10: Importance Analysis - Washing Machine

adjusting the scheme to account for this difference may be necessary. However, in this case because the failure frequencies are so low that a dramatic increase in the importance rank will not occur. Even though differences in the importance rank and service efficiency index exist, the service quality category associated with the importance rank does not recommend design changes that will increase manufacturing costs. However, design changes that do not sacrifice manufacturing efficiency for increased service efficiency are acceptable.

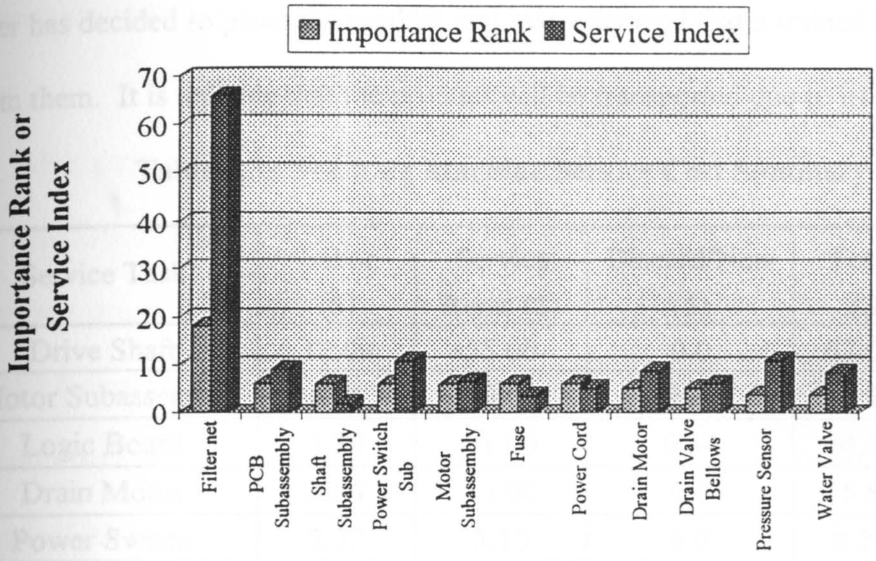

Figure 5.11: Importance Rank vs. Service Index-Washing Machine

Entry	Name	Id. Number	Function of System
System being analyzed	Washing Machine	—	To clean clothes and other items
Next higher assembly	—	—	—

Task	Importance Rank	Service Classification: Preventive Service	Service Classification: Corrective Service	Corrective Categories: AAC	RIP	DSCD	SCRN	REP	NL	Service Organization: First Tier	Second Tier	Third Tier
PCB Subassembly	18		X			X					X	
Filter net	18		X		X					X		
Shaft Subassembly	12		X			X					X	
Drain Motor	10		X			X					X	
Power Switch Sub	6		X			X					X	
Motor Subassembly	6		X			X					X	
Fuse	6		X			X					X	
Power Cord	6		X			X					X	
Drain Valve Bellows	5		X			X					X	
Pressure Sensor	4		X			X					X	
Water Valve	4		X			X					X	

Figure 5.12: Maintenance Organization Worksheet - Washing Machine

Figure 5.12 predicts how the washing machine will be serviced during the operating life of the product. All the procedures will be performed in the location where the user has decided to place the product and many demand that a trained technician perform them. It is unlikely that the product will be transported due to its large size.

Table 5.3: Washing Machine Service Cost Summary

Service Task	Labor ($)	Service Items ($)	Discard/New ($)	Total ($)	Service Life ($)
Drive Shaft	12.09	55.00	0.0	67.09	0.16
Motor Subassembly	6.06	39.00	0.20	45.26	0.0181
Logic Board	3.30	61.00	0.34	64.64	0.3103
Drain Motor	3.84	12.00	0.0	15.84	0.038
Power Switch	2.77	5.50	0.0	8.27	0.0099
Fuse	2.11	0.10	0.0	2.21	0.0009
Pressure Sensor	2.73	13.00	0.0	15.73	0.0063
Water Valve	3.58	9.70	0.0	13.28	0.0027
Drain Valve Bellows	2.92	1.90	0.0	4.82	0.0039
Power Cord	4.48	16.0	0.20	20.68	0.0083
Filter Net [1]	0.23	0.00	0.00	0.23	5.52
Total	44.11	213.20	0.74	258.05	6.08

[1] Will likely be performed by the end-user

The service efficiency for the washing machine is calculated by using Eq. (4.2) and for the data used here is approximately 65%. The equation yields such a high number because the failure frequencies for the tasks other than cleaning the filter net are relatively low and do not greatly influence the outcome of the equation.

5.6 Summary

In this chapter it has been shown that a relationship between importance rank and service efficiency exists for the products examined in this project. In the printer case study, tasks that intuitively should be quick and easy to perform, whereas such. It appeared to the author that the printer was well designed for serviceability. In fact each product examined was relatively easy to service once the service procedures became familiar.

Also, procedures for determining how the service task should be classified and "who" should perform the procedure were tested. In the case studies examined, the maintenance organization which was predicted by the flow charts contained in Figs. 3.2, 3.3, and 3 4 directly agreed with the current system used by the manufacturer. A case study was also conducted on a product which is considered a throw-away item to determine if the methodology would predict it to be non-repairable.

References

1. Subramani A., " Development of a Design for Service Methodology", Ph. D. Dissertation, University of Rhode Island, 1992.

2. Whyland C., "Development of a Design for Service Database", M.S. Thesis, University of Rhode Island, 1993.

3. "The Life Expectancy/Replacement Picture", <u>Appliance Manufacturer</u>, September, 1992, 46-47.

Chapter 6: Conclusion

The objective of this research was to provide a service engineer with a system that could be used to setup a service strategy for a product. The strategy developed consists of a system to rank service procedures based on their frequencies of failure and the consequence of the failures occurring. Also included in the service strategy is a method for determining essential information about "who" will service, "where" the product will be serviced and if the procedure should be corrective or preventive in nature.

Additions to the current DFS methodology previously developed at URI, were examined. The currently-used measure for determining service efficiency is a cost based measure and could mislead engineers by providing false high values. A time-based index was proposed based on criteria for theoretically necessary removal of parts or subassemblies and disassembly operations. These criteria where in turn developed by examining products supplied from industry. More importantly, the initial investigation of a relationship between the importance of a procedure and its service efficiency index was undertaken. It appears that tasks which should intuitively have a high efficiency, also have a high importance ranking. Therefore, it is proposed that the importance rank of a task can be used as a design goal for the service efficiency of the task. Also from examining case studies, the need for time penalties for operator position became apparent. The time standard databases previously developed could not correctly predict the service time when the operator was placed in an position where movement was restricted or was uncomfortable.

Lastly, the strategy developed for this project was tested on products supplied from industry.

While examining products for serviceability it became apparent that many of the same DFA principles that allow for design improvements will also positively effect the efficiency of the service tasks. However, some care must be taken when using DFA. When designing with snap fits, which are an efficient fastening method, the design must be durable enough to endure the unfastening and refastening associated with service procedures. Also, if tools are required to release the snaps, access points should be designed into the product. In general it is the author's opinion that the use of DFA principles will inherently increase the serviceability of the product.

6.1 Future Work

There are several suggestions for future research that became apparent while working on this project. First, more case studies need to be undertaken to ensure that the importance analysis procedure developed here can be applied to a broad range of products. Also, the existence of a relationship between the importance rank and service efficiency should be validated by more case studies. It is also recommended that the application of the DFS methodology to automotive damageability be investigated.

Unrelated to serviceability, but nevertheless relevant, research focusing on the ergonomic impact on product assembly is gaining interest as manufacturers try to reduce medical expenses. The time penalties associated with uncomfortable position; investigated in this work, may provide a bridge between economic and ergonomic considerations.

6.1.1 Refining Importance Analysis

Currently the relationship between importance rank and the service efficiency index has only been tested on four case studies. Many of the service tasks on these case studies had a low importance rank due to the fact that they either had a very low failure frequency and/or had a low consequence ranking. The need exists to further validate the apparent relationship between importance and efficiency by examining products which contain procedures with high importance ranking.

The service quality criteria presented in Table 3.3 could also benefit from further investigation of case studies. By determining the importance rank, recommendations for designing the product to a level of serviceability that corresponds with the importance of the task may be possible. These levels of serviceability and the related ranges of importance where determined by considering the serviceability of many products, but surely improvements can be made in this area as well.

6.1.2 Service Efficiency Measures

The criteria for the determination of which part/subassembly removals and disassembly operations can be considered theoretically necessary is not yet considered finalized. Upon examining cases studies, the criteria used are continually being modified because it becomes necessary to include a task which was previously unknown. Hence, it is recommended that case studies continue to be examined to ensure that the criteria developed encompass every possible contingency.

6.1.3 Investigation of DFS Applications in Damageability

It is suggested that the potential use of the application of DFS in automobile damageability be investigated. It has been the authors experience that the cost of repairing even minor damage to a body panel is usually exorbitant.

The current DFS methodology already contains time standard databases for spot welding and spot weld unfastening. However, it does not contain the information necessary for estimating the time needed to perform the necessary finishing operations such as sanding and painting. The importance of the procedure could then be determined and compared to the time based service efficiency of the task. It is suspected by the author, that the importance of the procedure will be much larger than the related service efficiency index. This would suggest that perhaps the body designers should seriously consider improving the serviceability of exterior body panels.

6.1.4 Ergonomic Assembly Practices

As medical costs continue to increase, companies are looking for ways to reduce medical claims by improving the ergonomics of the workplace. However, just increasing the ergonomics of workplace conditions in not enough. Designing components of a product such that they are ergonomically easy to assemble is also an important area to investigate. Other benefits besides reducing medical expenses will also materialize from ergonomic design. Increases in worker productivity can be realized by reducing the losses from operator fatigue, reduced well-being, absenteeism, and quality and reliability deficits associated with lowered employee moral.

This topic was uncovered while investigating the time penalties associated with the effect of operator position. It is suspected that repeatably placing workers in uncomfortable positions will not only increase the labor cost of the task at hand, but will increase the long term medical expenses paid out by the employer. Initial investigation of this topic has lead to some interesting findings. For example consider screw fastening, the torquing of screws imposes stresses on the hand/wrist when repetitive use and high torque forces are used. Both hand tools and the "kick back" from a power tool may contribute to illness or injuries in assembly operations. Since a key issue in DFA is reducing the number of separate fasteners, it is suspected that the use of DFA principles in design may not only reduce the manufacturing cost, but may also in turn provide long term health benefits.

Appendix A

Position Modifier Data

Table A.1: Position Modified Screwing Operations-Six Repetitions

Worker Position	Modifier	DFS Disassembly	DFS Reassembly	DFS Total Time
Normal - Comfortable	1.0	60.2	72.0	132.2
Stand on Ladder	1.1	66.2	79.2	145.4
Kneel on one or both knees	1.2	72.2	86.4	158.6
Stooping from a standing position	1.2	72.2	86.4	158.6
Stretch over obstacle	1.2	72.2	86.4	158.6
Lie on back	1.2	72.2	86.4	158.6
Squat on knees	1.3	78.3	93.6	171.9
Lie on side	1.5	90.3	108.0	198.3

Table A.2: Six Screws-Lying on Side

Trial Number	Disassembly Time	Reassembly Time	Total Time
1	87	132	219
2	76	93	169
3	78	96	174
4	95	109	204
5	97	113	210
6	95	101	196
7	88	103	191
8	71	109	180
9	103	92	195
10	74	102	176
11	79	102	181
12	73	113	186
13	91	102	193
14	83	117	200
15	90	95	185
Average	85.33	105.27	190.60
STDEV	9.90	10.6	13.93
T	-1.94	-1.00	-2.140
95%	2.145	2.145	2.145
Means are	Equal	Equal	Equal
Actual	1.42	1.46	1.44
Suggested	1.5	1.5	1.5

Table A.3: Six Screws-Kneeling

Trial Number	Disassembly Time	Reassembly Time	Total Time
1	63	100	163
2	60	84	144
3	72	87	159
4	70	84	154
5	77	88	165
6	78	78	156
7	71	93	164
8	77	102	179
9	80	85	165
10	63	85	148
11	67	83	150
12	60	87	147
13	71	78	149
14	76	81	157
15	60	83	143
Average	69.67	86.53	156.20
STDEV	7.12	7.0	9.86
T	-1.38	0.07	-0.943
95%	2.145	2.145	2.145
Means are	Equal	Equal	Equal
Actual	1.16	1.20	1.18
Suggested	1.2	1.2	1.2

Table A.4: Six Screws-Stretching Over an Obstacle

Trial Number	Disassembly Time	Reassembly Time	Total Time
1	81	99	180
2	72	77	149
3	71	78	149
4	69	82	151
5	83	73	156
6	68	75	143
7	63	82	145
8	60	82	142
9	70	91	161
10	79	105	184
11	70	90	160
12	78	94	172
13	74	100	174
14	74	99	173
15	60	75	135
Average	71.47	86.80	158.27
STDEV	7.04	10.7	15.22
T	-0.40	0.15	-0.085
95%	2.145	2.145	2.145
Means are	Equal	Equal	Equal
Actual	1.19	1.21	1.20
Suggested	1.2	1.2	1.2

Name	Cat.	Repeat Count	Tool Acquisition	Dis. Time	Modified Dis. Time	Item Set-aside	Total Time
Shutter	Part	1	0.00	3.60	5.40	1.40	6.8
Unplug from Wire Harness	Oper.	1	0.00	2.50	3.75	0.00	3.75
Unhook Cable	Oper.	1	0.00	6.00	9.00	0.00	9
Drain Motor Screws	Part	4	4.20	20.00	30.00	1.40	129.8
Drain Motor Sub.	Sub.	1	0.00	4.40	6.60	1.40	8
					Disassembly Time =		157.35

Name	Cat.	Repeat Count	Tool Acquisition	Re. Time	Modified Re. Time	Item Acquisition	Total Time
Drain Motor Sub.	Sub.	1	0.00	9.50	14.25	1.40	15.65
Drain Motor Screws	Part	4	4.20	23.70	35.55	1.40	152
Fasten Cable	Oper.	1	0.00	5.50	8.25	0.00	8.25
Snap Harness	Oper.	1	0.00	3.10	4.65	0.00	4.65
Shutter	Part	1	0.00	2.90	4.35	1.40	5.75
					Reassembly Time =		186.3

Figure A.1: Disassembly & Reassembly Worksheets for Drain Motor

Name	Cat.	Repeat Count	Tool Acquisition	Dis. Time	Modified Dis. Time	Item Set-aside	Total Time
Comp. Cover Screw	Part	7	4.20	8.00	12.00	1.40	98
Comp. Assy. Cover	Part	1	0.00	1.40	2.10	3.40	5.5
Relay Clamp Cover	Part	1	4.20	4.50	6.75	1.40	12.35
Relay Cover	Part	1	0.00	3.40	5.10	1.40	6.5
Unfasten Comp. Connect.	Oper.	2	0.00	5.00	7.50	0.00	15
Compressor Bolts	Part	4	4.2	11.3	16.95	1.4	77.6
Compressor	Sub.	1	0.00	5.00	7.50	3.40	10.9
Compressor Gromet	Part	4	0.00	3.60	5.40	1.40	27.2
					Disassembly Time =		253.05

Name	Cat.	Repeat Count	Tool Acquisition	Re. Time	Modified Re. Time	Item Acquisition	Total Time
Compressor Gromet	Part	4	0.00	5.80	8.70	1.40	40.4
Compressor	Sub.	1	0.00	9.50	14.25	3.40	17.65
Compressor Bolts	Part	4	4.20	19.40	29.10	1.40	126.2
Attach Comp. Connect.	Oper.	2	0.00	6.20	9.30	1.40	21.4
Relay Cover	Part	1	0.00	7.30	10.95	0.00	10.95
Relay Cover Clamp	Part	1	0	12.7	19.05	1.4	20.45
Comp. Assy. Cover	Part	1	0.00	4.90	7.35	3.40	10.75
Comp. Cover Screws	Part	7	4.20	10.60	15.90	1.40	125.3
					Reassembly Time =		373.1

Figure A.2: Disassembly & Reassembly Worksheets for Compressor

Name	Cat.	Repeat Count	Tool Acquisition	Dis. Time	Modified Dis. Time	Item Set-aside	Total Time
Comp. Cover Screw	Part	7	4.20	8.00	12.00	1.40	98
Comp. Assy. Cover	Part	1	0.00	1.40	2.10	3.40	5.5
Junction Case Screws	Part	2	4.20	8.00	12.00	1.40	31
Unplug Capacitors	Oper.	4	0.00	3.60	5.40	0.00	21.6
Unplug Defrost Timer	Oper.	4	0.00	3.60	5.40	0.00	21.6
Case Junction Sub.	Sub.	1	0	1.4	2.1	3.4	5.5
Reorientation	Oper.	1	0.00	4.50	6.75	0.00	6.75
Defrost Timer Screw	Part	2	4.20	8.00	12.00	1.40	31
Defrost Timer	Part	1	0.00	2.40	3.60	1.40	5
					Disassembly Time =		225.95

Name	Cat.	Repeat Count	Tool Acquisition	Re. Time	Modified Re. Time	Item Acquisition	Total Time
Defrost Timer	Sub.	1	0.00	4.90	7.35	1.40	8.75
Defrost Timer Screw	Part	2	4.20	10.60	15.90	1.40	38.8
Reorientation	Oper.	1	0.00	4.50	6.75	0.00	6.75
Case Junction Sub.	Sub.	1	0.00	4.90	7.35	3.40	10.75
Attach Defrost Timer	Oper.	4	0.00	4.40	6.60	0.00	26.4
Attach Compacitor	Oper.	4	0	4.4	6.6	0	26.4
Junction Case Screws	Part	2	4.20	10.60	15.90	1.40	38.8
Comp. Assy. Cover	Part	1	0.00	4.90	7.35	3.40	10.75
Comp. Cover Screws	Part	7	4.20	10.60	15.90	1.40	125.3
					Reassembly Time =		292.7

Figure A.3: Disassembly & Reassembly Worksheets for Defrost Timer

Name	Cat.	Repeat Count	Tool Acquisition	Dis. Time	Modified Dis. Time	Item Set-aside	Total Time
Comp. Cover Screw	Part	7	4.20	8.00	12.00	1.40	98
Comp. Assy. Cover	Part	1	0.00	1.40	2.10	3.40	5.5
Unsnap Fan Wires	Oper.	2	0.00	1.80	2.70	0.00	5.4
Fan Bracket Screws	Part	4	4.20	19.90	29.85	1.40	129.2
Fan Motor Assembly	Part	1	0.00	2.40	3.60	1.40	5
Fan Spring	Part	1	4.2	6.4	9.6	1.4	15.2
Fan Propeller	Part	1	0.00	3.60	5.40	1.40	6.8
Motor Mounting Nuts	Part	2	0.00	2.40	3.60	1.40	10
Motor Screws	Part	2	4.20	8.00	12.00	1.40	31
Motor Bracket	Part	1	0.00	2.40	3.60	1.40	5
Citcuit Fan Motor	Sub.	1	0.00	3.40	5.10	1.40	6.5
					Disassembly Time =		317.60

Name	Cat.	Repeat Count	Tool Acquisition	Re. Time	Modified Re. Time	Item Acquisition	Total Time
Citcuit Fan Motor	Sub.	1	0.00	4.90	7.35	1.40	8.75
Motor Bracket	Part	1	0.00	4.90	7.35	1.40	8.75
Motor Screws	Part	2	4.20	13.80	20.70	1.40	48.4
Motor Mounting Nuts	Part	2	0.00	4.90	7.35	1.40	17.5
Fan Propeller	Part	1	0.00	5.80	8.70	1.40	10.1
Fan Spring	Part	1	4.2	5.8	8.7	1.4	14.3
Fan Motor Assembly	Part	1	0.00	4.90	7.35	1.40	8.75
Fan Bracket Screws	Part	4	4.20	26.60	39.90	1.40	169.4
Snap Fan Wires	Oper.	2	0.00	2.20	3.30	0.00	6.6
Comp. Assy. Cover	Part	1	0.00	4.90	7.35	3.40	10.75
Comp. Cover Screws	Part	7	4.20	10.60	15.90	1.40	125.3
					Reassembly Time =		428.6

Figure A.4: Disassembly & Reassembly Worksheets for Compressor Fan

Appendix B

DFS Worksheets For Case Studies

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Carriage Motor

File name: HPDFS.DFS
Last modification: Wed Sep 14 20:46:52 1994
Date of printing: Sat Mar 11 18:03:49 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Sub	Un...	Output tray Asse...	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
2	Sub	Un...	Top Cover Assem...	1	Yes	0.00	4.20	4.20	0.04	0.00	-	snap fit unfasten & remo...
3	Oper	Un...	Push fit unfasten	1	Yes	0.00	6.60	6.60	0.05	0.00	-	standard disassembly o...
4	Oper	Un...	Push fit unfasten	1	Yes	0.00	5.00	5.00	0.04	0.00	-	standard disassembly o...
5	Oper	Un...	Push fit unfasten	1	Yes	0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
6	Oper	Un...	Push fit unfasten	1	Yes	0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
7	Oper	Un...	Push fit unfasten	1	Yes	0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
8	Sub	Un...	Mechanism Chas...	1	Yes	0.00	5.80	5.80	0.05	0.00	-	remove
9	Part	Un...	Service Stat. scre...	2	Yes	4.20	12.70	29.60	0.25	0.00	-	screw unfasten & remove
10	Sub	Un...	Service Stat. Assy	1	Yes	0.00	5.70	5.70	0.05	0.00	-	remove
11	Oper	Un...	Removing Drive B...	1		0.00	-	5.00	0.04	0.00	-	library disassembly oper...
12	Part	Un...	Motor Screws	2	Yes	4.20	12.70	29.60	0.25	0.00	-	screw unfasten & remove
13	Part	Un...	Damper Belt	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
14	Sub	Srvc	Carriage Motor As...	1	Yes	0.00	7.50	7.50	0.06	0.00	5.00	remove

Figure B.1: Disassembly Worksheet - Carriage Motor

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Carriage Motor

File name: HPDFS.DFS
Last modification: Wed Sep 14 20:46:52 1994
Date of printing: Sat Mar 11 18:03:49 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Sub	Srvc	Carriage Motor As...	1	Yes	0.00	1.40	14.30	15.70	0.13	0.00	5.00
2	Part	Re...	Damper Belt	1	Yes	0.00	1.40	14.30	15.70	0.13	0.00	-
3	Part	Re...	Motor Screws	2	Yes	4.20	1.40	19.40	45.80	0.38	0.00	-
4	Oper	Re...	Attaching Drive Belt	1		0.00	-	-	8.00	0.07	0.00	-
5	Sub	Re...	Service Stat. Assy	1	Yes	0.00	1.40	4.90	6.30	0.05	0.00	-
6	Part	Re...	Service Stat. scre...	2	Yes	4.20	1.40	19.40	45.80	0.38	0.00	-
7	Sub	Re...	Mechanism Chas...	1	Yes	0.00	3.40	7.00	10.40	0.09	0.00	-
8	Oper	Re...	Plug in cable	1	Yes	0.00	-	4.40	4.40	0.04	0.00	-
9	Oper	Re...	Plug in cable	1	Yes	0.00	-	4.40	4.40	0.04	0.00	-
10	Oper	Re...	Plug in Harness	1	Yes	0.00	-	4.40	4.40	0.04	0.00	-
11	Oper	Re...	Plug in Harness	1	Yes	0.00	-	6.20	6.20	0.05	0.00	-
12	Oper	Re...	Plug in Harness	1	Yes	0.00	-	8.40	8.40	0.07	0.00	-
13	Sub	Re...	Top Cover Assem...	1	Yes	0.00	3.40	9.00	12.40	0.10	0.00	-
14	Sub	Re...	Output tray Asse...	1	Yes	0.00	3.40	7.00	10.40	0.09	0.00	-

Figure B.2: Reassembly Worksheet - Carriage Motor

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Logic Board

File name: HPDFS.DFS
Last modification: Fri Oct 21 10:43:19 1994
Date of printing: Sat Mar 11 18:13:33 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Sub	Un...	Output tray Asse...	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
2	Sub	Un...	Top Cover Assem...	1	Yes	0.00	6.00	6.00	0.05	0.00	-	snap fit unfasten & remo...
3	Oper	Un...	Push fit unfasten	1	Yes	0.00	6.60	6.60	0.05	0.00	-	standard disassembly o...
4	Oper	Un...	Push fit unfasten	1	Yes	0.00	5.00	5.00	0.04	0.00	-	standard disassembly o...
5	Oper	Un...	Push fit unfasten	1	Yes	0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
6	Oper	Un...	Push fit unfasten	1	Yes	0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
7	Oper	Un...	Push fit unfasten	1	Yes	0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
8	Sub	Un...	Mechanism Chas...	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
9	Oper	Un...	Push fit unfasten	1	Yes	0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
10	Part	Un...	Mounting Screws	6	Yes	4.20	9.40	60.60	0.50	0.00	-	screw unfasten & remove
11	Part	Srvc	Logic PCA	1	Yes	0.00	6.70	6.70	0.06	0.00	50.00	remove

Figure B.3: Disassembly Worksheet - Logic Board

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Logic Board

File name: HPDFS.DFS
Last modification: Fri Oct 21 10:43:19 1994
Date of printing: Sat Mar 11 18:13:33 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Part	Srvc	Logic PCA	1	Yes	0.00	3.40	7.00	10.40	0.09	0.00	50.00
2	Part	Re...	Mounting Screws	6	Yes	4.20	1.40	13.80	95.40	0.80	0.00	-
3	Oper	Re...	Plug in Cable	1	Yes	0.00	-	4.40	4.40	0.04	0.00	-
4	Sub	Re...	Mechanism Chas...	1	Yes	0.00	3.40	7.00	10.40	0.09	0.00	-
5	Oper	Re...	Plug in cable	1	Yes	0.00	-	4.40	4.40	0.04	0.00	-
6	Oper	Re...	Plug in cable	1	Yes	0.00	-	4.40	4.40	0.04	0.00	-
7	Oper	Re...	Plug in Harness	1	Yes	0.00	-	4.40	4.40	0.04	0.00	-
8	Oper	Re...	Plug in Harness	1	Yes	0.00	-	6.20	6.20	0.05	0.00	-
9	Oper	Re...	Plug in Harness	1	Yes	0.00	-	8.40	8.40	0.07	0.00	-
10	Sub	Re...	Top Cover Assem...	1	Yes	0.00	3.40	2.90	6.30	0.05	0.00	-
11	Sub	Re...	Output tray Asse...	1	Yes	0.00	3.40	7.00	10.40	0.09	0.00	-

Figure B.4: Reassembly Worksheet - Logic Board

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Clutch Replacement

File name: HPDFS.DFS
Last modification: Fri Dec 30 09:11:02 1994
Date of printing: Sat Mar 11 18:13:33 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Sub	Un...	Output tray Asse...	1	Yes	0.00	3.80	3.80	0.03	0.00	-	screw unfasten & remove
2	Sub	Un...	Top Cover Assem...	1	Yes	0.00	6.00	6.00	0.05	0.00	-	snap fit unfasten & remo...
3	Oper	Un...	Push fit unfasten	1	Yes	0.00	5.00	5.00	0.04	0.00	-	standard disassembly o...
4	Oper	Un...	Reorientation	1		0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
5	Part	Un...	Retainer Shaft	1	Yes	4.20	4.60	8.80	0.07	0.00	-	snap fit unfasten & remo...
6	Oper	Un...	Push fit unfasten	1	Yes	0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
7	Part	Un...	Carriage shaft	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
8	Oper	Un...	Snap fit unfasten	1	Yes	0.00	1.80	1.80	0.01	0.00	-	standard disassembly o...
9	Oper	Un...	Unfeed Encoder ...	1		0.00	-	2.00	0.02	0.00	-	library disassembly oper...
10	Part	Un...	Encoder Strip	1	Yes	0.00	4.20	4.20	0.04	0.00	-	snap fit unfasten & remo...
11	Oper	Un...	Undo Belt From Roll	1		0.00	-	3.75	0.03	0.00	-	library disassembly oper...
12	Oper	Un...	Removing Drive B...	1		0.00	-	5.00	0.04	0.00	-	library disassembly oper...
13	Sub	Un...	Carriage Assy	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
14	Part	Un...	Roller cover screws	2	Yes	4.20	9.40	23.00	0.19	0.00	-	screw unfasten & remove
15	Sub	Un...	Paper Guide Assy	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
16	Part	Un...	Ink spill well	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
17	Part	Un...	Roller pivet restric	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
18	Sub	Un...	Roll Shaft fastener	1	Yes	0.00	3.20	3.20	0.03	0.00	-	snap fit unfasten & remo...
19	Oper	Un...	Removing Spg fro...	1		4.20	-	8.20	0.07	0.00	-	library disassembly oper...
20	Part	Un...	Roller tension sprin	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
21	Part	Un...	Screw	1	Yes	4.20	12.70	16.90	0.14	0.00	-	screw unfasten & remove
22	Part	Un...	Horz Shaft Fastner	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
23	Sub	Un...	Roller assembly	1	Yes	0.00	5.80	5.80	0.05	0.00	-	remove
24	Part	Dscd	Remove Gear	1		23.50	16.90	40.40	0.34	0.95	1.00	press fit unfasten & rem...
25	Sub	Srvc	Clutch Mechanism	1		0.00	7.80	7.80	0.07	0.00	1.00	push fit unfasten & remo...

Figure B.5: Disassembly Worksheet - Clutch Replacement

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Clutch Replacement

File name: HPDFS.DFS
Last modification: Fri Dec 30 09:11:02 1994
Date of printing: Sat Mar 11 18:13:33 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Sub	Srvc	Clutch Mechanism	1		0.00	1.40	5.80	7.20	0.06	0.00	1.00
2	Part	New	Remove Gear	1		23.50	1.40	7.50	32.40	0.27	0.00	1.00
3	Sub	Re...	Roller assembly	1	Yes	0.00	3.40	7.00	10.40	0.09	0.00	-
4	Part	Re...	Horz Shaft Fastner	1	Yes	0.00	1.40	5.40	6.80	0.06	0.00	-
5	Part	Re...	Screw	1	Yes	4.20	1.40	19.40	25.00	0.21	0.00	-
6	Part	Re...	Roller tension sprin	1	Yes	0.00	1.40	10.90	12.30	0.10	0.00	-
7	Oper	Re...	Pull Spring over T...	1		4.20	-	-	11.20	0.09	0.00	-
8	Sub	Re...	Roll Shaft fastener	1	Yes	0.00	1.40	9.00	10.40	0.09	0.00	-
9	Part	Re...	Roller pivet restric	1	Yes	0.00	1.40	3.80	5.20	0.04	0.00	-
10	Part	Re...	Ink spill well	1	Yes	0.00	1.40	3.80	5.20	0.04	0.00	-
11	Sub	Re...	Paper Guide Assy	1	Yes	0.00	1.40	5.40	6.80	0.06	0.00	-
12	Part	Re...	Roller cover screws	2	Yes	4.20	1.40	13.80	34.60	0.29	0.00	-
13	Sub	Re...	Carriage Assy	1	Yes	0.00	3.40	4.90	8.30	0.07	0.00	-
14	Part	Re...	Encoder Strip	1	Yes	0.00	3.40	2.20	5.60	0.05	0.00	-
15	Oper	Re...	Feed Encoder Strip	1		0.00	-	-	3.00	0.03	0.00	-
16	Oper	Re...	Pull strip over knob	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
17	Oper	Re...	Attaching Drive Belt	1		0.00	-	-	8.00	0.07	0.00	-
18	Oper	Re...	Placing Belt on Roll	1		0.00	-	-	5.00	0.04	0.00	-
19	Part	Re...	Carriage shaft	1	Yes	0.00	1.40	4.90	6.30	0.05	0.00	-
20	Oper	Re...	Push shaft into 51	1	Yes	0.00	-	4.40	4.40	0.04	0.00	-
21	Part	Re...	Retainer Shaft	1	Yes	0.00	1.40	9.00	10.40	0.09	0.00	-
22	Oper	Re...	Resetting Printer	1		0.00	-	-	600.00	5.00	0.00	-
23	Oper	Re...	Plug in Harness	1	Yes	0.00	-	8.40	8.40	0.07	0.00	-
24	Sub	Re...	Top Cover Assem...	1	Yes	0.00	3.40	2.90	6.30	0.05	0.00	-
25	Sub	Re...	Output tray Asse...	1	Yes	0.00	3.40	5.40	8.80	0.07	0.00	-

Figure B.6: Reassembly Worksheet - Clutch Replacement

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Roller Replacement

File name: HPDFS.DFS
Last modification: Wed Oct 19 09:10:54 1994
Date of printing: Sat Mar 11 18:13:33 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Sub	Un...	Output tray Asse...	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
2	Sub	Un...	Top Cover Assem...	1	Yes	0.00	6.00	6.00	0.05	0.00	-	snap fit unfasten & remo...
3	Oper	Un...	Push fit unfasten	1	Yes	0.00	5.00	5.00	0.04	0.00	-	standard disassembly o...
4	Oper	Un...	Reorientation	1		0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
5	Part	Un...	Retainer Shaft	1	Yes	4.20	4.60	8.80	0.07	0.00	-	snap fit unfasten & remo...
6	Oper	Un...	Push fit unfasten	1	Yes	0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
7	Part	Un...	Carriage shaft	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
8	Oper	Un...	Snap fit unfasten	1	Yes	0.00	1.80	1.80	0.01	0.00	-	standard disassembly o...
9	Oper	Un...	Unfeed Encoder ...	1		0.00	-	2.00	0.02	0.00	-	library disassembly oper...
10	Part	Un...	Encoder Strip	1	Yes	0.00	4.20	4.20	0.04	0.00	-	snap fit unfasten & remo...
11	Oper	Un...	Undo Belt From Roll	1		0.00	-	3.75	0.03	0.00	-	library disassembly oper...
12	Oper	Un...	Removing Drive B...	1		0.00	-	5.00	0.04	0.00	-	library disassembly oper...
13	Sub	Un...	Carriage Assy	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
14	Part	Un...	Roller cover screws	2	Yes	4.20	9.40	23.00	0.19	0.00	-	screw unfasten & remove
15	Sub	Un...	Paper Guide Assy	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
16	Part	Un...	Ink spill well	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
17	Part	Un...	Roller pivet restric	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
18	Sub	Un...	Roll Shaft fastener	1	Yes	0.00	3.20	3.20	0.03	0.00	-	snap fit unfasten & remo...
19	Oper	Un...	Removing Spg fro...	1		4.20	-	8.20	0.07	0.00	-	library disassembly oper...
20	Part	Un...	Roller tension sprin	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
21	Part	Un...	Screw	1	Yes	4.20	12.70	16.90	0.14	0.00	-	screw unfasten & remove
22	Part	Un...	Horz Shaft Fastner	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
23	Sub	Srvc	Roller assembly	1	Yes	0.00	5.80	5.80	0.05	0.00	10.00	remove

Figure B.7: Disassembly Worksheet - Roller Replacement

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Roller Replacement

File name: HPDFS.DFS
Last modification: Wed Oct 19 09:10:54 1994
Date of printing: Sat Mar 11 18:13:33 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Sub	Srvc	Roller assembly	1	Yes	0.00	3.40	7.00	10.40	0.09	0.00	10.00
2	Part	Re...	Horz Shaft Fastner	1	Yes	0.00	1.40	5.40	6.80	0.06	0.00	-
3	Part	Re...	Screw	1	Yes	4.20	1.40	19.40	25.00	0.21	0.00	-
4	Part	Re...	Roller tension sprin	1	Yes	0.00	1.40	10.90	12.30	0.10	0.00	-
5	Oper	Re...	Pull Spring over T...	1		4.20	-	-	11.20	0.09	0.00	-
6	Sub	Re...	Roll Shaft fastener	1	Yes	0.00	1.40	9.00	10.40	0.09	0.00	-
7	Part	Re...	Roller pivet restric	1	Yes	0.00	1.40	3.80	5.20	0.04	0.00	-
8	Part	Re...	Ink spill well	1	Yes	0.00	1.40	3.80	5.20	0.04	0.00	-
9	Sub	Re...	Paper Guide Assy	1	Yes	0.00	1.40	5.40	6.80	0.06	0.00	-
10	Part	Re...	Roller cover screws	2	Yes	4.20	1.40	13.80	34.60	0.29	0.00	-
11	Sub	Re...	Carriage Assy	1	Yes	0.00	3.40	4.90	8.30	0.07	0.00	-
12	Part	Re...	Encoder Strip	1	Yes	0.00	3.40	2.20	5.60	0.05	0.00	-
13	Oper	Re...	Feed Encoder Strip	1		0.00	-	-	3.00	0.03	0.00	-
14	Oper	Re...	Pull strip over knob	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
15	Oper	Re...	Attaching Drive Belt	1		0.00	-	-	8.00	0.07	0.00	-
16	Oper	Re...	Placing Belt on Roll	1		0.00	-	-	5.00	0.04	0.00	-
17	Part	Re...	Carriage shaft	1	Yes	0.00	1.40	4.90	6.30	0.05	0.00	-
18	Oper	Re...	Push shaft into 51	1	Yes	0.00	-	4.40	4.40	0.04	0.00	-
19	Part	Re...	Retainer Shaft	1	Yes	0.00	1.40	9.00	10.40	0.09	0.00	-
20	Oper	Re...	Resetting Printer	1		0.00	-	-	600.00	5.00	0.00	-
21	Oper	Re...	Plug in Harness	1	Yes	0.00	-	8.40	8.40	0.07	0.00	-
22	Sub	Re...	Top Cover Assem...	1	Yes	0.00	3.40	2.90	6.30	0.05	0.00	-
23	Sub	Re...	Output tray Asse...	1	Yes	0.00	3.40	5.40	8.80	0.07	0.00	-

Figure B.8: Reassembly Worksheet - Roller Replacement

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Pinch Roller

File name: HPDFS.DFS
Last modification: Fri Sep 16 12:03:44 1994
Date of printing: Sat Mar 11 18:13:33 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Sub	Un...	Output tray Asse...	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
2	Sub	Un...	Top Cover Assem...	1	Yes	0.00	6.00	6.00	0.05	0.00	-	snap fit unfasten & remo...
3	Oper	Un...	Push fit unfasten	1	Yes	0.00	5.00	5.00	0.04	0.00	-	standard disassembly o...
4	Oper	Un...	Reorientation	1		0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
5	Part	Un...	Retainer Shaft	1	Yes	4.20	4.60	8.80	0.07	0.00	-	snap fit unfasten & remo...
6	Oper	Un...	Push fit unfasten	1	Yes	0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
7	Part	Un...	Carriage shalt	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
8	Oper	Un...	Snap fit unfasten	1	Yes	0.00	1.80	1.80	0.01	0.00	-	standard disassembly o...
9	Oper	Un...	Unfeed Encoder ...	1		0.00	-	2.00	0.02	0.00	-	library disassembly oper...
10	Part	Un...	Encoder Strip	1	Yes	0.00	4.20	4.20	0.04	0.00	-	snap fit unfasten & remo...
11	Oper	Un...	Undo Belt From Roll	1		0.00	-	3.75	0.03	0.00	-	library disassembly oper...
12	Oper	Un...	Removing Drive B...	1		0.00	-	5.00	0.04	0.00	-	library disassembly oper...
13	Sub	Un...	Carriage Assy	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
14	Part	Un...	Roller cover screws	2	Yes	4.20	9.40	23.00	0.19	0.00	-	screw unfasten & remove
15	Sub	Un...	Paper Guide Assy	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
16	Part	Un...	Spring, Pinch Roller	3	Yes	4.20	7.80	27.60	0.23	0.00	-	snap fit unfasten & remo...
17	Part	Srvc	Pinch Roller	3	Yes	0.00	3.20	9.60	0.08	0.00	0.10	snap fit unfasten & remo...

Figure B.9: Disassembly Worksheet - Pinch Roller

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Pinch Roller

File name: HPDFS.DFS
Last modification: Sat Mar 11 19:09:34 1995
Date of printing: Sat Mar 11 19:15:40 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Part	Srvc	Pinch Roller	3	Yes	0.00	1.40	2.90	12.90	0.11	0.00	0.10
2	Part	Re...	Spring, Pinch Roller	3	Yes	0.00	1.40	8.60	30.00	0.25	0.00	-
3	Sub	Re...	Paper Guide Assy	1	Yes	0.00	1.40	5.40	6.80	0.06	0.00	-
4	Part	Re...	Roller cover screws	2	Yes	4.20	1.40	13.80	34.60	0.29	0.00	-
5	Sub	Re...	Carriage Assy	1	Yes	0.00	3.40	4.90	8.30	0.07	0.00	-
6	Part	Re...	Encoder Strip	1	Yes	0.00	3.40	2.20	5.60	0.05	0.00	-
7	Oper	Re...	Pull strip over knob	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
8	Part	Re...	Carriage shaft	1	Yes	0.00	1.40	4.90	6.30	0.05	0.00	-
9	Oper	Re...	Push shaft into 51	1	Yes	0.00	-	4.40	4.40	0.04	0.00	-
10	Part	Re...	Retainer Shaft	1	Yes	0.00	1.40	9.00	10.40	0.09	0.00	-
11	Oper	Re...	reorientation	1		0.00	-	4.50	4.50	0.04	0.00	-
12	Oper	Re...	Plug in Harness	1	Yes	0.00	-	8.40	8.40	0.07	0.00	-
13	Sub	Re...	Top Cover Assem...	1	Yes	0.00	3.40	2.90	6.30	0.05	0.00	-
14	Sub	Re...	Output tray Asse...	1	Yes	0.00	3.40	5.40	8.80	0.07	0.00	-
15	Oper	Re...	Attaching Drive Belt	1		0.00	-	-	8.00	0.07	0.00	-
16	Oper	Re...	Placing Belt on Roll	1		0.00	-	-	5.00	0.04	0.00	-
17	Oper	Re...	Feed Encoder Strip	1		0.00	-	-	3.00	0.03	0.00	-

Figure B.10: Reassembly Worksheet - Pinch Roller

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Ink Replacement

File name: HP550C.DFS
Last modification: Tue Jan 31 18:29:03 1995
Date of printing: Sun Mar 12 09:30:47 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Oper	Un...	Open cover	1		0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
2	Oper	Un...	Push Button	1		0.00	-	2.00	0.02	0.00	-	library disassembly oper...
3	Oper	Un...	Wait for poisition	1		0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
4	Part	Srvc	Unsnap Ink Cartri...	1		0.00	5.00	5.00	0.04	0.00	0.00	snap fit unfasten & remo...

Figure B.11: Disassembly Worksheet - Ink Replacement

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Ink Replacement

File name: HP550C.DFS
Last modification: Tue Jan 31 18:29:03 1995
Date of printing: Sun Mar 12 09:30:47 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Part	Srvc	Unsnap Ink Cartri...	1		0.00	1.40	2.20	3.60	0.03	0.00	0.00
2	Oper	Re...	reorientation	1		0.00	-	4.50	4.50	0.04	0.00	-
3	Oper	Re...	Push Button	1		0.00	-	-	2.00	0.02	0.00	-
4	Oper	Re...	reorientation	1		0.00	-	4.50	4.50	0.04	0.00	-

Figure B.12: Reassembly Worksheet - Ink Replacement

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Add Paper

File name: HP550C.DFS
Last modification: Tue Jan 31 18:54:54 1995
Date of printing: Sun Mar 12 09:30:47 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Oper	Un...	Slide paper catch	1		0.00	4.50	4.50	0.04	0.00	-	reorient & adjust

Figure B.13: Disassembly Worksheet - Add Paper

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Add Paper

File name: HP550C.DFS
Last modification: Tue Jan 31 18:54:54 1995
Date of printing: Sun Mar 12 09:30:47 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Part	Re...	Paper supply	1		0.00	1.40	4.90	6.30	0.05	0.00	-
2	Oper	Re...	reorientation	1		0.00	-	4.50	4.50	0.04	0.00	-

Figure B.14: Reassembly Worksheet - Add Paper

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Clear Paper Jam

File name: HP550C.DFS
Last modification: Tue Jan 31 18:47:57 1995
Date of printing: Sun Mar 12 09:30:47 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Sub	Un...	Output tray Asse...	1	Yes	0.00	5.80	5.80	0.05	0.00	-	remove
2	Oper	Un...	Clear Paper Jam	1		0.00	4.50	4.50	0.04	0.00	-	reorient & adjust

Figure B.15: Disassembly Worksheet - Clear Paper Jam

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Clear Paper Jam

File name: HP550C.DFS
Last modification: Tue Jan 31 18:47:57 1995
Date of printing: Sun Mar 12 09:30:47 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Oper	Re...	Align paper	1		0.00	-	4.50	4.50	0.04	0.00	-
2	Sub	Re...	Output tray Asse...	1	Yes	0.00	3.40	7.00	10.40	0.09	0.00	-

Figure B.16: Reassembly Worksheet - Clear Paper Jam

Compressor Fan Motor

Name	Cat.	Repeat Count	Tool Acquisition	Dis. Time	Modified Dis. Time	Item Set-aside	Total Time
Pull away from wall	Oper	1	0.00	38.10	38.10	0.00	38.1
Unplug from Wall	Oper	1	0.00	6.40	6.40	0.00	6.4
Comp. Cover Screw	Part	7	4.20	8.00	12.00	1.40	98
Comp. Assy. Cover	Part	1	0.00	1.40	2.10	3.40	5.5
Unsnap Fan Wires	Oper.	2	0.00	1.80	2.70	0.00	5.4
Fan Bracket Screws	Part	4	4.20	19.90	29.85	1.40	129.2
Fan Motor Assembly	Part	1	0.00	2.40	3.60	1.40	5
Fan Spring	Part	1	4.2	6.4	9.6	1.4	15.2
Fan Propeller	Part	1	0.00	3.60	5.40	1.40	6.8
Motor Mounting Nuts	Part	2	0.00	2.40	3.60	1.40	10
Motor Screws	Part	2	4.20	8.00	12.00	1.40	31
Motor Bracket	Part	1	0.00	2.40	3.60	1.40	5
Citcuit Fan Motor	Sub.	1	0.00	3.40	5.10	1.40	6.5

Disassembly Time = 362.10

Figure B.17: Disassembly Worksheet - Compressor Fan Motor

Compressor Fan Motor

Name	Cat.	Repeat Count	Tool Acquisition	Re. Time	Modified Re. Time	Item Acquisition	Total Time
Citcuit Fan Motor	Sub.	1	0.00	4.90	7.35	1.40	8.75
Motor Bracket	Part	1	0.00	4.90	7.35	1.40	8.75
Motor Screws	Part	2	4.20	13.80	20.70	1.40	48.4
Motor Mounting Nuts	Part	2	0.00	4.90	7.35	1.40	17.5
Fan Propeller	Part	1	0.00	5.80	8.70	1.40	10.1
Fan Spring	Part	1	4.2	5.8	8.7	1.4	14.3
Fan Motor Assembly	Part	1	0.00	4.90	7.35	1.40	8.75
Fan Bracket Screws	Part	4	4.20	26.60	39.90	1.40	169.4
Snap Fan Wires	Oper.	2	0.00	2.20	3.30	0.00	6.6
Comp. Assy. Cover	Part	1	0.00	4.90	7.35	3.40	10.75
Comp. Cover Screws	Part	7	4.20	10.60	15.90	1.40	125.3
Plug in Refrigerator	Oper.	1	0.00	4.40	4.40	0.00	4.4
Push against wall	Oper.	1	0.00	28.10	28.10	0.00	28.1

Reassembly Time = 461.1

Figure B.18: Reassembly Worksheet - Compressor Fan Motor

Compressor

Name	Cat.	Repeat Count	Tool Acquisition	Dis. Time	Modified Dis. Time	Item Set-aside	Total Time
Pull away from wall	Oper	1	0.00	38.10	38.10	0.00	38.1
Unplug from Wall	Oper	1	0.00	6.40	6.40	0.00	6.4
Comp. Cover Screw	Part	7	4.20	8.00	12.00	1.40	98
Comp. Assy. Cover	Part	1	0.00	1.40	2.10	3.40	5.5
Relay Clamp Cover	Part	1	4.20	4.50	6.75	1.40	12.35
Relay Cover	Part	1	0.00	3.40	5.10	1.40	6.5
Unfasten Comp. Connect.	Oper.	2	0.00	5.00	7.50	0.00	15
Unsnap Harness	Oper.	1	0.00	1.80	2.70	0.00	2.7
Remove Freon	Oper.	1	4.20	49.20	73.80	0.00	78
Cut Copper Tubes	Oper.	2	4.20	9.50	14.25	0.00	32.7
Compressor Bolts	Part	4	4.2	11.3	16.95	1.4	77.6
Compressor	Sub.	1	0.00	5.00	7.50	3.40	10.9
Compressor Grommet	Part	4	0.00	3.60	5.40	1.40	27.2

Disassembly Time = 410.95

Figure B.19: Disassembly Worksheet - Compressor

Compressor

Name	Cat.	Repeat Count	Tool Acquisition	Re. Time	Modified Re. Time	Item Acquisition	Total Time
Compressor Grommet	Part	4	0.00	5.80	8.70	1.40	40.4
Compressor	Sub.	1	0.00	9.50	14.25	3.40	17.65
Compressor Bolts	Part	4	4.20	19.40	29.10	1.40	126.2
Solder Tubing	Oper.	2	4.20	5.40	8.10	0.00	20.4
Charge Freon	Oper.	1	4.20	49.20	73.80	0.00	78
Snap harness to clamp	Oper.	1	0.00	2.20	3.30	0.00	3.3
Attach Comp. Connect.	Oper.	2	0.00	6.20	9.30	1.40	21.4
Relay Cover	Part	1	0.00	7.30	10.95	0.00	10.95
Relay Cover Clamp	Part	1	0.00	12.7	19.05	1.4	20.45
Comp. Assy. Cover	Part	1	0.00	4.90	7.35	3.40	10.75
Comp. Cover Screws	Part	7	4.20	10.60	15.90	1.40	125.3
Plug in Refrigerator	Oper.	1	0.00	4.40	4.40	0.00	4.4
Push against wall	Oper.	1	0.00	28.10	28.10	0.00	28.1

Reassembly Time = 507.3

Figure B.20: Reassembly Worksheet - Compressor

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Thermo Damper

File name: REFRIG.DFS
Last modification: Sun Jan 22 18:20:54 1995
Date of printing: Sun Mar 12 09:48:04 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Oper	Un...	Pull away from wall	1		0.00	-	38.10	0.32	0.00	-	library disassembly oper...
2	Oper	Un...	Unplug from wall	1		0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
3	Oper	Un...	Open door	1		0.00	-	2.00	0.02	0.00	-	library disassembly oper...
4	Part	Un...	Ref. shelf	2	Yes	0.00	4.80	9.60	0.08	0.00	-	remove
5	Sub	Un...	Veggie Ass. cove...	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
6	Sub	Un...	Veggie Ware sub	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
7	Oper	Un...	Lift chillroom cover	1	Yes	0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
8	Part	Un...	Chilled room tray	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
9	Part	Un...	Chilled Room Shelf	1	Yes	0.00	6.00	6.00	0.05	0.00	-	snap fit unfasten & remo...
10	Sub	Un...	Guide Chilled	1	Yes	0.00	6.00	6.00	0.05	0.00	-	snap fit unfasten & remo...
11	Part	Un...	Ref. Lamp Cover	1	Yes	0.00	5.00	5.00	0.04	0.00	-	snap fit unfasten & remo...
12	Part	Un...	Damper Cover Sc...	2	Yes	4.20	9.40	23.00	0.19	0.00	-	screw unfasten & remove
13	Part	Un...	Damper Cover Sc...	2	Yes	4.20	9.40	23.00	0.19	0.00	-	screw unfasten & remove
14	Oper	Un...	Unplug lamp harn...	1	Yes	0.00	2.50	2.50	0.02	0.00	-	standard disassembly o...
15	Sub	Un...	Damper	1	Yes	0.00	6.00	6.00	0.05	0.00	-	remove
16	Part	Un...	Top foam insulation	1	Yes	0.00	6.00	6.00	0.05	0.00	-	self-stick unfasten & re...
17	Part	Un...	Apply tape	4		0.00	6.00	24.00	0.20	0.00	-	self-stick unfasten & re...
18	Sub	Un...	Damper Spacer S...	1	Yes	0.00	6.70	6.70	0.06	0.00	-	remove
19	Part	Un...	Thermo Knob Da...	1	Yes	0.00	5.00	5.00	0.04	0.00	-	push fit unfasten & remo...
20	Part	Un...	Masking Tape	2	Yes	0.00	6.00	12.00	0.10	0.00	-	self-stick unfasten & re...
21	Oper	Un...	Attach tem sensor	1	Yes	0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
22	Oper	Un...	reorientation	1	Yes	0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
23	Part	Un...	Damper Spacer F...	1	Yes	0.00	6.00	6.00	0.05	0.00	-	self-stick unfasten & re...
24	Part	Un...	Masking Tape	2	Yes	0.00	6.00	12.00	0.10	0.00	-	self-stick unfasten & re...
25	Part	Un...	Clay	1	Yes	0.00	7.80	7.80	0.07	0.00	-	push fit unfasten & remo...
26	Sub	Un...	Thermo Damper ...	1	Yes	0.00	7.80	7.80	0.07	0.00	-	push fit unfasten & remo...
27	Part	Un...	Thermo Damper s...	2	Yes	4.20	9.40	23.00	0.19	0.00	-	screw unfasten & remove
28	Sub	Srvc	Thermo Damper ...	1	Yes	0.00	5.70	5.70	0.05	0.00	8.80	remove
29	Oper	Un...	Remove temp se...	1	Yes	0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...

Figure B.21: Disassembly Worksheet - Refrigerator Thermostat

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Thermo Damper

File name: REFRIG.DFS
Last modification: Sun Jan 22 18:20:54 1995
Date of printing: Sun Mar 12 09:48:04 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Oper	Re...	Feed temp sensor	1	Yes	0.00	-	4.40	4.40	0.04	0.00	-
2	Sub	Srvc	Thermo Damper ...	1	Yes	0.00	1.40	7.40	8.80	0.07	0.00	8.80
3	Part	Re...	Thermo Damper s...	2	Yes	4.20	1.40	13.80	34.60	0.29	0.00	-
4	Sub	Re...	Thermo Damper ...	1	Yes	0.00	1.40	5.80	7.20	0.06	0.00	-
5	Part	Re...	Clay	1	Yes	0.00	1.40	4.40	5.80	0.05	0.00	-
6	Part	Re...	Masking Tape	2	Yes	0.00	3.40	4.40	15.60	0.13	0.00	-
7	Part	Re...	Damper Spacer F...	1	Yes	0.00	3.40	5.80	9.20	0.08	0.00	-
8	Oper	Re...	reorientation	1	Yes	0.00	-	4.50	4.50	0.04	0.00	-
9	Oper	Re...	Detach Temp Se...	1	Yes	0.00	-	4.40	4.40	0.04	0.00	-
10	Part	Re...	Masking Tape	2	Yes	0.00	3.40	4.40	15.60	0.13	0.00	-
11	Part	Re...	Thermo Knob Da...	1	Yes	0.00	1.40	4.40	5.80	0.05	0.00	-
12	Sub	Re...	Damper Spacer S...	1	Yes	0.00	3.40	4.90	8.30	0.07	0.00	-
13	Part	Re...	Apply tape	4		0.00	3.40	4.40	31.20	0.26	0.00	-
14	Part	Re...	Top foam insulation	1	Yes	0.00	3.40	5.80	9.20	0.08	0.00	-
15	Sub	Re...	Damper	1	Yes	0.00	4.60	9.00	13.60	0.11	0.00	-
16	Oper	Re...	Plug in Lamps	1	Yes	0.00	-	3.10	3.10	0.03	0.00	-
17	Part	Re...	Damper Cover Sc...	2	Yes	4.20	1.40	13.80	34.60	0.29	0.00	-
18	Part	Re...	Damper Cover Sc...	2	Yes	4.20	1.40	13.80	34.60	0.29	0.00	-
19	Part	Re...	Ref. Lamp Cover	1	Yes	0.00	1.40	2.20	3.60	0.03	0.00	-
20	Sub	Re...	Guide Chilled	1	Yes	0.00	3.40	2.20	5.60	0.05	0.00	-
21	Part	Re...	Chilled Room Shelf	1	Yes	0.00	3.40	2.90	6.30	0.05	0.00	-
22	Part	Re...	Chilled room tray	1	Yes	0.00	3.40	4.90	8.30	0.07	0.00	-
23	Oper	Re...	Lift chillroom cover	1	Yes	0.00	-	4.50	4.50	0.04	0.00	-
24	Sub	Re...	Veggie Ware sub	1	Yes	0.00	3.40	3.80	7.20	0.06	0.00	-
25	Sub	Re...	Veggie Ass. cove...	1	Yes	0.00	3.40	3.80	7.20	0.06	0.00	-
26	Part	Re...	Ref. shelf	2	Yes	0.00	3.40	3.80	14.40	0.12	0.00	-
27	Oper	Re...	close door	1		0.00	-	-	2.00	0.02	0.00	-
28	Oper	Re...	Plug in	1		0.00	-	4.40	4.40	0.04	0.00	-
29	Oper	Re...	Push against wall	1		0.00	-	-	28.10	0.23	0.00	-

Figure B.22: Reassembly Worksheet - Refrigerator Thermostat

Defrost Timer

Name	Cat.	Repeat Count	Tool Acquisition	Dis. Time	Modified Dis. Time	Item Set-aside	Total Time
Pull away from wall	Oper	1	0.00	38.10	38.10	0.00	38.10
Unplug from Wall	Oper	1	0.00	6.40	6.40	0.00	6.40
Comp. Cover Screw	Part	7	4.20	8.00	12.00	1.40	98.00
Comp. Assy. Cover	Part	1	0.00	1.40	2.10	3.40	5.50
Junction Case Screws	Part	2	4.20	8.00	12.00	1.40	31.00
Unplug Capacitors	Oper.	4	0.00	3.60	5.40	0.00	21.60
Unplug Defrost Timer	Oper.	4	0.00	3.60	5.40	0.00	21.60
Case Junction Sub.	Sub.	1	0.00	1.40	2.10	3.40	5.50
Reorientation	Oper.	1	0.00	4.50	6.75	0.00	6.75
Defrost Timer Screw	Part	2	4.20	8.00	12.00	1.40	31.00
Defrost Timer	Part	1	0.00	2.40	3.60	1.40	5.00

Disassembly Time = 270.45

Figure B.23: Disassembly Worksheet - Defrost Timer

Defrost Timer

Name	Cat.	Repeat Count	Tool Acquisition	Re. Time	Modified Re. Time	Item Acquisition	Total Time
Defrost Timer	Sub.	1	0.00	4.90	7.35	1.40	8.75
Defrost Timer Screw	Part	2	4.20	10.60	15.90	1.40	38.8
Reorientation	Oper.	1	0.00	4.50	6.75	0.00	6.75
Case Junction Sub.	Sub.	1	0.00	4.90	7.35	3.40	10.75
Attach Defrost Timer	Oper.	4	0.00	4.40	6.60	0.00	26.4
Attach Capacitor Connct.	Oper.	4	0	4.4	6.6	0	26.4
Junction Case Screws	Part	2	4.20	10.60	15.90	1.40	38.8
Comp. Assy. Cover	Part	1	0.00	4.90	7.35	3.40	10.75
Comp. Cover Screws	Part	7	4.20	10.60	15.90	1.40	125.3
Plug in Refrigerator	Oper.	1	0.00	4.40	4.40	0.00	4.4
Push against wall	Oper.	1	0.00	28.10	28.10	0.00	28.1

Reassembly Time = 325.2

Figure B.24: Reassembly Worksheet - Defrost Timer

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Thermostat Fr.

File name: REFRIG.DFS
Last modification: Sun Jan 22 18:20:58 1995
Date of printing: Sun Mar 12 09:48:04 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Oper	Un...	Pull away from wall	1		0.00	-	38.10	0.32	0.00	-	library disassembly oper...
2	Oper	Un...	Unplug Refig	1		0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
3	Oper	Un...	Open door	1	.	0.00	-	2.00	0.02	0.00	-	library disassembly oper...
4	Sub	Un...	Freezer shelf sub	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
5	Part	Un...	Thermo Box Scre...	2	Yes	4.20	12.70	29.60	0.25	0.00	-	screw unfasten & remove
6	Oper	Un...	Snap fit unfasten	1	Yes	0.00	1.80	1.80	0.01	0.00	-	standard disassembly o...
7	Oper	Un...	unfasten connect	2	Yes	0.00	6.40	12.80	0.11	0.00	-	standard disassembly o...
8	Oper	Un...	Snap fit unfasten	1	Yes	0.00	1.80	1.80	0.01	0.00	-	standard disassembly o...
9	Sub	Un...	Freezer Thermo B...	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
10	Part	Un...	Thermostat Screws	2	Yes	4.20	12.70	29.60	0.25	0.00	-	screw unfasten & remove
11	Part	Dscd	Upper Foam Seal	1	Yes	0.00	8.80	8.80	0.07	0.00	0.10	self-stick unfasten & re...
12	Part	Dscd	Lower Foam Seal	1	Yes	4.20	15.00	19.20	0.16	0.00	0.10	self-stick unfasten & re...
13	Oper	Un...	Snap fit unfasten	1	Yes	0.00	1.80	1.80	0.01	0.00	-	standard disassembly o...
14	Sub	Srvc	Thermostat Sub	1	Yes	0.00	3.80	3.80	0.03	0.00	9.80	remove

Figure B.25: Disassembly Worksheet - Freezer Thermostat

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Thermostat Fr.

File name: REFRIG.DFS
Last modification: Sun Jan 22 18:20:58 1995
Date of printing: Sun Mar 12 09:48:04 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Sub	Srvc	Thermostat Sub	1	Yes	0.00	1.40	7.40	8.80	0.07	0.00	9.80
2	Oper	Re...	Snap thermocou...	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
3	Part	New	Lower Foam Seal	1	Yes	0.00	3.40	5.80	9.20	0.08	0.00	0.10
4	Part	New	Upper Foam Seal	1	Yes	0.00	3.40	5.80	9.20	0.08	0.00	0.10
5	Part	Re...	Thermostat Screws	2	Yes	4.20	1.40	14.90	36.80	0.31	0.00	-
6	Sub	Re...	Freezer Thermo B...	1	Yes	0.00	3.40	4.90	8.30	0.07	0.00	-
7	Oper	Re...	Snap connector	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
8	Oper	Re...	push connectors	2	Yes	0.00	-	4.40	8.80	0.07	0.00	-
9	Oper	Re...	Snap Thermo Bo...	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
10	Part	Re...	Thermo Box Scre...	2	Yes	4.20	1.40	13.80	34.60	0.29	0.00	-
11	Sub	Re...	Freezer shelf sub	1	Yes	0.00	3.40	4.90	8.30	0.07	0.00	-
12	Oper	Re...	Close door	1		0.00	-	-	2.00	0.02	0.00	-
13	Oper	Re...	Push fit refasten	1		0.00	-	4.40	4.40	0.04	0.00	-
14	Oper	Re...	Push against wall	1		0.00	-	-	28.10	0.23	0.00	-

Figure B.26: Reassembly Worksheet - Freezer Thermostat

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Ref Door

File name: REFRIG.DFS
Last modification: Sun Jan 22 18:21:19 1995
Date of printing: Sun Mar 12 10:55:58 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Oper	Un...	Pull away from wall	1		0.00	-	38.10	0.32	0.00	-	library disassembly oper...
2	Oper	Un...	Unplug from wall	1		0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
3	Oper	Un...	open fre door	1		0.00	-	2.00	0.02	0.00	-	library disassembly oper...
4	Part	Un...	Upper Hinge Cap	1	Yes	4.20	4.60	8.80	0.07	0.00	-	snap fit unfasten & remo...
5	Part	Un...	Freezer Hinge Bolt	4	Yes	4.20	9.40	41.80	0.35	0.00	-	screw unfasten & remove
6	Part	Un...	Upper Hinge	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
7	Part	Un...	Upper Hinge Shim	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
8	Sub	Un...	Freezer Door Sub	1	Yes	0.00	6.00	6.00	0.05	0.00	-	remove
9	Oper	Un...	open ref door	1		0.00	-	2.00	0.02	0.00	-	library disassembly oper...
10	Part	Un...	Egg Tray	2	Yes	0.00	3.80	7.60	0.06	0.00	-	remove
11	Part	Un...	Bottle Guard	1	Yes	0.00	6.00	6.00	0.05	0.00	-	push fit unfasten & remo...
12	Part	Un...	Upper Guard Fre...	2	Yes	0.00	5.60	11.20	0.09	0.00	-	push fit unfasten & remo...
13	Part	Un...	Lower Guard Fre...	1	Yes	0.00	6.20	6.20	0.05	0.00	-	push fit unfasten & remo...
14	Part	Un...	Small Hinge Screw	1	Yes	4.20	9.40	13.60	0.11	0.00	-	screw unfasten & remove
15	Part	Un...	Refig Hinge Bolt	2	Yes	4.20	13.00	30.20	0.25	0.00	-	screw unfasten & remove
16	Part	Un...	Mid Hinge	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
17	Part	Un...	Mid Hinge Shim	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
18	Sub	Srvc	Refrig Door Sub	1	Yes	0.00	7.70	7.70	0.06	0.00	40.00	remove

Figure B.27: Disassembly Worksheet - Refrigerator Door

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Ref Door

File name: REFRIG.DFS
Last modification: Sun Jan 22 18:21:19 1995
Date of printing: Sun Mar 12 10:55:58 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Sub	Srvc	Refrig Door Sub	1	Yes	0.00	6.30	13.70	20.00	0.17	0.00	40.00
2	Part	Re...	Mid Hinge Shim	1	Yes	0.00	1.40	4.90	6.30	0.05	0.00	-
3	Part	Re...	Mid Hinge	1	Yes	0.00	1.40	4.90	6.30	0.05	0.00	-
4	Part	Re...	Refig Hinge Bolt	2	Yes	4.20	1.40	17.40	41.80	0.35	0.00	-
5	Part	Re...	Small Hinge Screw	1	Yes	4.20	1.40	13.80	19.40	0.16	0.00	-
6	Part	Re...	Lower Guard Fre...	1	Yes	0.00	2.60	5.80	8.40	0.07	0.00	-
7	Part	Re...	Upper Guard Fre...	2	Yes	0.00	2.00	5.80	15.60	0.13	0.00	-
8	Part	Re...	Bottle Guard	1	Yes	0.00	3.40	5.80	9.20	0.08	0.00	-
9	Part	Re...	Egg Tray	2	Yes	0.00	1.40	4.90	12.60	0.11	0.00	-
10	Oper	Re...	close ref door	1		0.00	-	-	2.00	0.02	0.00	-
11	Sub	Re...	Freezer Door Sub	1	Yes	0.00	4.60	9.30	13.90	0.12	0.00	-
12	Part	Re...	Upper Hinge Shim	1	Yes	0.00	1.40	4.90	6.30	0.05	0.00	-
13	Part	Re...	Upper Hinge	1	Yes	0.00	1.40	4.90	6.30	0.05	0.00	-
14	Part	Re...	Freezer Hinge Bolt	4	Yes	4.20	1.40	13.80	65.00	0.54	0.00	-
15	Part	Re...	Upper Hinge Cap	1	Yes	0.00	1.40	2.90	4.30	0.04	0.00	-
16	Oper	Re...	close door	1		0.00	-	-	2.00	0.02	0.00	-
17	Oper	Re...	Plug in ref	1		0.00	-	4.40	4.40	0.04	0.00	-
18	Oper	Re...	Push against wall	1		0.00	-	-	28.10	0.23	0.00	-

Figure B.28: Reassembly Worksheet - Refrigerator Door

Lower Door Hinge

Name	Cat.	Repeat Count	Tool Acquisition	Dis. Time	Modified Dis. Time	Item Set-aside	Total Time
Pull away from wall	Oper.	1	0.00	38.10	38.10	0.00	38.10
Unplug from wall	Oper.	1	0.00	6.40	6.40	0.00	6.40
Open freezer door	Oper.	1	0.00	2.00	2.00	0.00	2.00
Upper hinge cap	Part	1	4.20	3.20	3.20	1.40	8.80
Freezer Hinge Bolt	Part	4	4.20	8.00	8.00	1.40	41.80
Upper Hinge	Part	1	0.00	2.40	2.40	1.40	3.80
Upper Hinge Shim	Part	1	0.00	2.40	2.40	1.40	3.80
Freezer Door Sub	Sub	1	0.00	1.4	1.40	4.60	6.00
Open Ref. Door	Oper.	1	0.00	2.00	2.00	0.00	2.00
Small Hinge Screw	Part	1	4.20	8.00	8.00	1.40	13.60
Refrig Hinge Bolt	Part	2	4.20	11.60	11.60	1.40	30.20
Mid Hinge	Part	1	0.00	2.40	2.40	1.40	3.80
Mid Hinge Shim	Part	1	0.00	2.40	2.40	1.40	3.80
Refrig. Door Sub	Sub	1	0.00	1.40	1.40	6.30	7.70
Water cover tray screw	Part	3	4.20	11.30	13.56	1.40	49.08
Water Cover Tray Sub	Sub	1	0.00	7.50	9.00	1.40	10.40
Lower Hinge Bolt	Part	4	4.20	11.30	13.56	1.40	64.04
Lower Hinge Sub	Sub	1	0.00	2.40	2.88	1.40	4.28
Lower Hinge Shim	Part	1	0.00	2.40	2.88	1.40	4.28

Disassembly Time = 303.88

Figure B.29: Disassembly Worksheet - Lower Door Hinge

Lower Door Hinge

Name	Cat.	Repeat Count	Tool Acquisition	Re. Time	Modified Re. Time	Item Acquisition	Total Time
Lower Hinge Shim	Part	1	0.00	4.90	5.88	1.40	7.28
Lower Hinge Sub	Sub	1	0.00	4.90	5.88	1.40	7.28
Lower Hinge Bolt	Part	4	4.20	19.40	23.28	1.40	102.92
Water Cover Tray Sub	Sub	1	0.00	4.40	5.28	1.40	6.68
Water cover tray screw	Part	3	4.20	13.80	16.56	1.40	58.08
Refrig. Door Sub	Sub	1	0.00	13.70	13.70	6.30	20.00
Mid Hinge Shim	Part	1	0.00	4.90	4.90	1.40	6.30
Mid Hinge	Part	1	0.00	4.90	4.90	1.40	6.30
Refrig Hinge Bolt	Part	2	4.20	17.40	17.40	1.40	41.80
Small Hinge Screw	Part	1	4.20	13.80	13.80	1.40	19.40
Close Ref. Door	Oper.	1	0.00	2.00	2.00	0.00	2.00
Freezer Door Sub	Sub	1	0.00	9.30	9.30	4.60	13.90
Upper Hinge Shim	Part	1	0.00	4.90	4.90	1.40	6.30
Upper Hinge	Part	1	0.00	4.90	4.90	1.40	6.30
Freezer Hinge Bolt	Part	4	4.20	13.80	13.80	1.40	65.00
Upper hinge cap	Part	1	0.00	2.90	2.90	1.40	4.30
Close freezer door	Oper.	1	0.00	2.00	2.00	0.00	2.00
Plug in Refrigerator	Oper.	1	0.00	4.40	4.40	0.00	4.40
Push against wall	Oper.	1	0.00	28.10	28.10	0.00	28.10

Reassembly Time = 408.34

Figure B.30: Reassembly Worksheet - Lower Door Hinge

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
FR Fan Motor

File name: REFRIG.DFS
Last modification: Sun Jan 22 18:21:04 1995
Date of printing: Sun Mar 12 10:55:58 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools... $	Servi... Disca... Items $	Description
1	Oper	Un...	Pull away from wall	1		0.00	-	38.10	0.32	0.00	-	library disassembly oper...
2	Oper	Un...	Unplug Refig	1		0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
3	Oper	Un...	Open door	1		0.00	-	2.00	0.02	0.00	-	library disassembly oper...
4	Sub	Un...	Freezer shelf sub	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
5	Part	Un...	Fzr Rear Screw C...	3	Yes	0.00	5.00	15.00	0.12	0.00	-	push fit unfasten & remo...
6	Part	Un...	Fzr Rear Screws	3	Yes	4.20	9.40	32.40	0.27	0.00	-	screw unfasten & remove
7	Sub	Un...	Evaporator Fzr Co...	1	Yes	0.00	6.70	6.70	0.06	0.00	-	snap fit unfasten & remo...
8	Oper	Un...	Unclip harness	1	Yes	0.00	6.60	6.60	0.05	0.00	-	standard disassembly o...
9	Oper	Un...	Unsnap wires	4	Yes	0.00	1.80	7.20	0.06	0.00	-	standard disassembly o...
10	Part	Un...	Rear Evap Cov S...	2	Yes	4.20	9.40	23.00	0.19	0.00	-	screw unfasten & remove
11	Sub	Un...	Rear Fan Sub	1	Yes	0.00	6.70	6.70	0.06	0.00	-	remove
12	Part	Un...	Remove Tape	2		0.00	6.00	12.00	0.10	0.00	-	self-stick unfasten & re...
13	Part	Un...	White Foam Seal	1	Yes	0.00	6.00	6.00	0.05	0.00	-	self-stick unfasten & re...
14	Oper	Un...	Flip Over	1	Yes	0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
15	Part	Un...	Fan Fastener Spri...	1	Yes	4.20	14.00	18.20	0.15	0.00	-	push fit unfasten & remo...
16	Part	Un...	Freezer Fan Blade	1	Yes	0.00	7.80	7.80	0.07	0.00	-	push fit unfasten & remo...
17	Part	Un...	C\L Bracket Screws	2	Yes	4.20	9.40	23.00	0.19	0.00	-	screw unfasten & remove
18	Part	Un...	C\L Motor Bracket	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
19	Sub	Srvc	Freezer Motor Sub	1	Yes	0.00	4.80	4.80	0.04	0.00	9.10	remove
20	Part	Un...	Rubber Motor Bu...	2	Yes	0.00	5.00	10.00	0.08	0.00	-	push fit unfasten & remo...

Figure B.31: Disassembly Worksheet - Freezer Fan Motor

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
FR Fan Motor

File name: REFRIG.DFS
Last modification: Sun Jan 22 18:21:04 1995
Date of printing: Sun Mar 12 10:55:58 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools... $	Serv... or N... Item...
1	Part	Re...	Rubber Motor Bu...	2	Yes	0.00	1.40	4.40	11.60	0.10	0.00	-
2	Sub	Srvc	Freezer Motor Sub	1	Yes	0.00	3.40	4.90	8.30	0.07	0.00	9.10
3	Part	Re...	C\L Motor Bracket	1	Yes	0.00	1.40	4.90	6.30	0.05	0.00	-
4	Part	Re...	C\L Bracket Screws	2	Yes	4.20	1.40	13.80	34.60	0.29	0.00	-
5	Part	Re...	Freezer Fan Blade	1	Yes	0.00	1.40	4.40	5.80	0.05	0.00	-
6	Part	Re...	Fan Fastener Spri...	1	Yes	0.00	1.40	5.80	7.20	0.06	0.00	-
7	Oper	Re...	Flip Over	1	Yes	0.00	-	4.50	4.50	0.04	0.00	-
8	Part	Re...	White Foam Seal	1	Yes	0.00	3.40	4.40	7.80	0.07	0.00	-
9	Part	Re...	Remove Tape	2		0.00	3.40	4.40	15.60	0.13	0.00	-
10	Sub	Re...	Rear Fan Sub	1	Yes	0.00	3.40	9.40	12.80	0.11	0.00	-
11	Part	Re...	Rear Evap Cov S...	2	Yes	4.20	1.40	13.80	34.60	0.29	0.00	-
12	Oper	Re...	Snap Wire Harness	4	Yes	0.00	-	2.20	8.80	0.07	0.00	-
13	Oper	Re...	Clip Harness	1	Yes	0.00	-	10.00	10.00	0.08	0.00	-
14	Sub	Re...	Evaporator Fzr Co...	1	Yes	0.00	3.40	4.90	8.30	0.07	0.00	-
15	Part	Re...	Fzr Rear Screws	3	Yes	4.20	1.40	13.80	49.80	0.41	0.00	-
16	Part	Re...	Fzr Rear Screw C...	3	Yes	0.00	1.40	4.40	17.40	0.14	0.00	-
17	Sub	Re...	Freezer shelf sub	1	Yes	0.00	3.40	4.90	8.30	0.07	0.00	-
18	Oper	Re...	close door	1		0.00	-	-	2.00	0.02	0.00	-
19	Oper	Re...	Plug in	1		0.00	-	4.40	4.40	0.04	0.00	-
20	Oper	Re...	Push against wall	1		0.00	-	-	28.10	0.23	0.00	-

Figure B.32: Reassembly Worksheet - Freezer Fan Motor

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Fre Door

File name: REFRIG.DFS
Last modification: Sun Jan 22 18:21:23 1995
Date of printing: Sun Mar 12 11:40:32 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools... $	Servi... Disca... Items $	Description
1	Oper	Un...	Pull away from wall	1		0.00	-	38.10	0.32	0.00	-	library disassembly oper...
2	Oper	Un...	Unplug from wall	1		0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
3	Oper	Un...	open door	1		0.00	-	2.00	0.02	0.00	-	library disassembly oper...
4	Part	Un...	Upper Guard Fre...	1	Yes	0.00	6.20	6.20	0.05	0.00	-	push fit unfasten & remo...
5	Part	Un...	Lower Guard Fre...	1	Yes	0.00	6.20	6.20	0.05	0.00	-	push fit unfasten & remo...
6	Part	Un...	Upper Hinge Cap	1	Yes	4.20	4.60	8.80	0.07	0.00	-	snap fit unfasten & remo...
7	Part	Un...	Freezer Hinge Bolt	4	Yes	4.20	9.40	41.80	0.35	0.00	-	screw unfasten & remove
8	Part	Un...	Upper Hinge	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
9	Part	Un...	Upper Hinge Shim	1	Yes	0.00	3.80	3.80	0.03	0.00	-	remove
10	Sub	Srvc	Freezer Door Sub	1	Yes	0.00	6.00	6.00	0.05	0.00	20.00	remove

Figure B.33: Disassembly Worksheet - Freezer Door

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Fre Door

File name: REFRIG.DFS
Last modification: Sun Jan 22 18:21:23 1995
Date of printing: Sun Mar 12 11:40:32 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Sub	Srvc	Freezer Door Sub	1	Yes	0.00	4.60	9.30	13.90	0.12	0.00	20.00
2	Part	Re...	Upper Hinge Shim	1	Yes	0.00	1.40	4.90	6.30	0.05	0.00	-
3	Part	Re...	Upper Hinge	1	Yes	0.00	1.40	4.90	6.30	0.05	0.00	-
4	Part	Re...	Freezer Hinge Bolt	4	Yes	4.20	1.40	13.80	65.00	0.54	0.00	-
5	Part	Re...	Upper Hinge Cap	1	Yes	0.00	1.40	2.90	4.30	0.04	0.00	-
6	Part	Re...	Lower Guard Fre...	1	Yes	0.00	2.60	5.80	8.40	0.07	0.00	-
7	Part	Re...	Upper Guard Fre...	1	Yes	0.00	2.60	5.80	8.40	0.07	0.00	-
8	Oper	Re...	close door	1		0.00	-	-	2.00	0.02	0.00	-
9	Oper	Re...	Push fit refasten	1		0.00	-	4.40	4.40	0.04	0.00	-
10	Oper	Re...	Push against wall	1		0.00	-	-	28.10	0.23	0.00	-

Figure B.34: Reassembly Worksheet - Freezer Door

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Freezer Bulb

File name: REFRIG.DFS
Last modification: Mon Feb 27 16:20:42 1995
Date of printing: Sun Mar 12 11:40:32 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Oper	Un...	Pull away from wall	1		0.00	-	38.10	0.32	0.00	-	library disassembly oper...
2	Oper	Un...	Unplug from wall	1		0.00	6.40	6.40	0.05	0.00	-	standard disassembly o...
3	Oper	Un...	Open Door	1		0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
4	Sub	Un...	Freezer shelf sub	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
5	Part	Un...	Thermo Box Scre...	2	Yes	4.20	12.70	29.60	0.25	0.00	-	screw unfasten & remove
6	Oper	Un...	Unsnap thermo box	1	Yes	0.00	1.80	1.80	0.01	0.00	-	standard disassembly o...
7	Oper	Un...	Unfasten connect	2	Yes	0.00	6.40	12.80	0.11	0.00	-	standard disassembly o...
8	Oper	Un...	Unsnap wire harn...	1	Yes	0.00	1.80	1.80	0.01	0.00	-	standard disassembly o...
9	Sub	Un...	Freezer Thermo B...	1	Yes	0.00	4.80	4.80	0.04	0.00	-	remove
10	Part	Srvc	Fre Lamp	1	Yes	0.00	10.40	10.40	0.09	0.00	0.00	screw unfasten & remove

Figure B.35: Disassembly Worksheet - Freezer Bulb

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Freezer Bulb

File name: REFRIG.DFS
Last modification: Mon Feb 27 16:20:42 1995
Date of printing: Sun Mar 12 11:40:32 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Part	Srvc	Fre Lamp	1	Yes	0.00	3.40	10.60	14.00	0.12	0.00	0.00
2	Sub	Re...	Freezer Thermo B...	1	Yes	0.00	3.40	4.90	8.30	0.07	0.00	-
3	Oper	Re...	Snap connector	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
4	Oper	Re...	push connectors	2	Yes	0.00	-	4.40	8.80	0.07	0.00	-
5	Oper	Re...	Snap Thermo Bo...	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
6	Part	Re...	Thermo Box Scre...	2	Yes	4.20	1.40	13.80	34.60	0.29	0.00	-
7	Sub	Re...	Freezer shelf sub	1	Yes	0.00	3.40	4.90	8.30	0.07	0.00	-
8	Oper	Re...	reorientation	1		0.00	-	4.50	4.50	0.04	0.00	-
9	Oper	Re...	Push fit refasten	1		0.00	-	4.40	4.40	0.04	0.00	-
10	Oper	Re...	Push against wall	1		0.00	-	-	28.10	0.23	0.00	-

Figure B.36: Reassembly Worksheet - Freezer Bulb

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Refrig Bulb

File name: REFRIG.DFS
Last modification: Mon Feb 27 17:30:03 1995
Date of printing: Sun Mar 12 11:40:32 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Oper	Un...	Pull away from wall	1		0.00	-	38.10	0.32	0.00	-	library disassembly oper...
2	Oper	Un...	Unplug from wall	1		0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
3	Oper	Un...	Open door	1		0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
4	Part	Un...	Ref. shelf	2	Yes	0.00	4.80	9.60	0.08	0.00	-	remove
5	Part	Un...	Ref. Lamp Cover	1	Yes	0.00	5.00	5.00	0.04	0.00	-	snap fit unfasten & remo...
6	Part	Un...	Lamps	1	Yes	0.00	10.40	10.40	0.09	0.00	-	screw unfasten & remove

Figure B.37: Disassembly Worksheet - Refrigerator Bulb

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Refrig Bulb

File name: REFRIG.DFS
Last modification: Mon Feb 27 17:30:03 1995
Date of printing: Sun Mar 12 11:40:32 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Aoq... sec	Item Aoqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Part	Re...	Lamps	1	Yes	0.00	3.40	10.60	14.00	0.12	0.00	-
2	Part	Re...	Ref. Lamp Cover	1	Yes	0.00	1.40	2.20	3.60	0.03	0.00	-
3	Part	Re...	Ref. shelf	2	Yes	0.00	3.40	3.80	14.40	0.12	0.00	-
4	Oper	Re...	Close door	1		0.00	-	4.50	4.50	0.04	0.00	-
5	Oper	Re...	Plug in	1		0.00	-	4.40	4.40	0.04	0.00	-
6	Oper	Re...	Push against wall	1		0.00	-	-	28.10	0.23	0.00	-

Figure B.38: Reassembly Worksheet - Refrigerator Bulb

Water Tray

Name	Cat.	Repeat Count	Tool Acquisition	Dis. Time	Modified Dis. Time	Item Set-aside	Total Time
Water Cover Screws	Part	3	4.20	11.30	13.56	1.40	49.08
Water Tray Cover Sub	Sub.	1	0.00	7.50	9.00	1.40	10.4
Water Tray	Part	1	0.00	4.00	4.80	13.70	18.5

Disassembly Time = 77.98

Figure B.39: Disassembly Worksheet - Water Tray

Water Tray

Name	Cat.	Repeat Count	Tool Acquisition	Re. Time	Modified Re. Time	Item Acquisition	Total Time
Water Tray	Part	1	0.00	4.00	4.80	13.70	18.5
Water Tray Cover Sub	Sub.	1	0.00	5.80	6.96	1.40	8.36
Water Cover Screws	Part	3	4.20	19.40	23.28	1.40	78.24

Reassembly Time = 105.1

Figure B.40: Reassembly Worksheet - Water Tray

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
PCB Subassembly x

File name: WASHMAC.DFS
Last modification: Sun Mar 12 15:00:40 1995
Date of printing: Sun Mar 12 15:05:29 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Sub	Srvc	pcb sub	1	Yes	0.00	4.60	4.90	9.50	0.08	0.00	61.00
2	Part	Re...	inner pcb screw	2	Yes	6.30	1.40	13.80	36.70	0.31	0.00	-
3	Oper	Re...	flip to pcb	1	Yes	0.00	-	4.50	4.50	0.04	0.00	-
4	Part	Re...	outer pcb screw	2	Yes	6.30	1.40	13.80	36.70	0.31	0.00	-
5	Part	Re...	long pcb screw	2	Yes	6.30	1.40	13.80	36.70	0.31	0.00	-
6	Oper	Re...	snap cable conn...	12	Yes	0.00	-	3.10	37.20	0.31	0.00	-
7	Oper	Re...	reorient panel	1	Yes	0.00	-	4.50	4.50	0.04	0.00	-
8	Oper	Re...	snap control panel	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
9	Part	Re...	control panel scr...	2	Yes	6.30	1.40	13.80	36.70	0.31	0.00	-
10	Part	New	screw covers	2	Yes	0.00	1.40	2.20	7.20	0.06	0.00	0.17
11	Oper	Re...	close lid	1	Yes	0.00	-	-	2.00	0.02	0.00	-
12	Oper	Re...	Plug in washer	1		0.00	-	4.40	4.40	0.04	0.00	-

Figure B.44: Reassembly Worksheet - PCB Washing Machine

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Power Svitch Sub x

File name: WASHMAC.DFS
Last modification: Sun Mar 12 15:01:12 1995
Date of printing: Sun Mar 12 15:05:29 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Oper	Un...	unplug washer	1		0.00	6.40	6.40	0.05	0.00	-	standard disassembly o...
2	Oper	Un...	Pull away from wall	1		0.00	-	38.10	0.32	0.00	-	library disassembly oper...
3	Part	Un...	rear top cover scr...	2	Yes	6.30	9.40	25.10	0.21	0.00	-	screw unfasten & remove
4	Part	Un...	hot water hose	1		0.00	10.60	10.60	0.09	0.00	-	screw unfasten & remove
5	Part	Un...	cold water hose	1		0.00	10.60	10.60	0.09	0.00	-	screw unfasten & remove
6	Part	Un...	inlet seals	2	Yes	6.30	5.20	16.70	0.14	0.00	-	snap fit unfasten & remo...
7	Oper	Un...	Snap fit unfasten	1	Yes	0.00	3.20	3.20	0.03	0.00	-	standard disassembly o...
8	Oper	Un...	reorient to covers...	1	Yes	0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
9	Oper	Un...	Snap cable conn...	4	Yes	0.00	2.50	10.00	0.08	0.00	-	standard disassembly o...
10	Part	Un...	power switch screw	2	Yes	6.30	9.40	25.10	0.21	0.00	-	screw unfasten & remove
11	Sub	Srvc	power switch	1	Yes	0.00	5.00	5.00	0.04	0.00	5.50	remove

Figure B.45: Disassembly Worksheet - Power Switch

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Power Switch Sub x

File name: WASHMAC.DFS
Last modification: Sun Mar 12 15:01:12 1995
Date of printing: Sun Mar 12 15:05:29 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Sub	Srvc	power switch	1	Yes	0.00	2.60	4.90	7.50	0.06	0.00	5.50
2	Part	Re...	power switch screw	2	Yes	6.30	1.40	13.80	36.70	0.31	0.00	-
3	Oper	Re...	snap cable conn...	4	Yes	0.00	-	3.10	12.40	0.10	0.00	-
4	Oper	Re...	reorient tc covers...	1	Yes	0.00	-	4.50	4.50	0.04	0.00	-
5	Oper	Re...	snap tc cover sub	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
6	Part	Re...	inlet seals	2	Yes	0.00	2.00	4.30	12.60	0.11	0.00	-
7	Part	Re...	cold water hose	1		0.00	2.60	13.80	16.40	0.14	0.00	-
8	Part	Re...	hot water hose	1		0.00	2.60	13.80	16.40	0.14	0.00	-
9	Part	Re...	rear top cover scr...	2	Yes	6.30	1.40	13.80	36.70	0.31	0.00	-
10	Oper	Re...	Push against wall	1		0.00	-	-	28.10	0.23	0.00	-
11	Oper	Re...	Push fit refasten	1		0.00	-	4.40	4.40	0.04	0.00	-

Figure B.46: Reassembly Worksheet - Power Switch

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Pressure Sensor x

File name: WASHMAC.DFS
Last modification: Sun Mar 12 15:02:00 1995
Date of printing: Sun Mar 12 15:05:29 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Oper	Un...	unplug washer	1		0.00	6.40	6.40	0.05	0.00	-	standard disassembly o...
2	Oper	Un...	Pull away from wall	1		0.00	-	38.10	0.32	0.00	-	library disassembly oper...
3	Part	Un...	rear top cover scr...	2	Yes	6.30	9.40	25.10	0.21	0.00	-	screw unfasten & remove
4	Part	Un...	hot water hose	1		0.00	10.60	10.60	0.09	0.00	-	screw unfasten & remove
5	Part	Un...	cold water hose	1		0.00	10.60	10.60	0.09	0.00	-	screw unfasten & remove
6	Part	Un...	inlet seals	2	Yes	6.30	5.20	16.70	0.14	0.00	-	snap fit unfasten & remo...
7	Oper	Un...	unsnap to cover s...	1	Yes	0.00	3.20	3.20	0.03	0.00	-	standard disassembly o...
8	Oper	Un...	reorient to covers...	1	Yes	0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
9	Part	Un...	press. sensor scr...	2	Yes	6.30	9.40	25.10	0.21	0.00	-	screw unfasten & remove
10	Sub	Srvc	press. sensor sub	1	Yes	0.00	5.00	5.00	0.04	0.00	13.00	remove
11	Oper	Un...	unsnap lead wire...	1	Yes	0.00	1.80	1.80	0.01	0.00	-	standard disassembly o...
12	Oper	Un...	unsnap guide cla...	1	Yes	0.00	1.80	1.80	0.01	0.00	-	standard disassembly o...
13	Oper	Un...	unfasten water g...	1	Yes	0.00	6.40	6.40	0.05	0.00	-	standard disassembly o...

Figure B.47: Disassembly Worksheet - Pressure Sensor

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Pressure Sensor x

File name: WASHMAC.DFS
Last modification: Sun Mar 12 15:02:00 1995
Date of printing: Sun Mar 12 15:05:29 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Oper	Re...	connect water gu...	1	Yes	0.00	-	5.80	4.80	0.04	0.00	-
2	Oper	Re...	snap guide clamp	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
3	Oper	Re...	snap lead wire-p.s.	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
4	Sub	Srvc	press. sensor sub	1	Yes	0.00	2.60	4.90	7.50	0.06	0.00	13.00
5	Part	Re...	press. sensor scr...	2	Yes	6.30	1.40	13.80	36.70	0.31	0.00	-
6	Oper	Re...	reorient to covers...	1	Yes	0.00	-	4.50	4.50	0.04	0.00	-
7	Oper	Re...	snap to cover sub	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
8	Part	Re...	inlet seals	2	Yes	0.00	2.00	2.90	9.80	0.08	0.00	-
9	Part	Re...	cold water hose	1		0.00	2.60	13.80	16.40	0.14	0.00	-
10	Part	Re...	hot water hose	1		0.00	2.60	13.80	16.40	0.14	0.00	-
11	Part	Re...	rear top cover scr...	2	Yes	6.30	1.40	13.80	36.70	0.31	0.00	-
12	Oper	Re...	Push against wall	1		0.00	-	-	28.10	0.23	0.00	-
13	Oper	Re...	Push fit refasten	1		0.00	-	4.40	4.40	0.04	0.00	-

Figure B.48: Reassembly Worksheet - Pressure Sensor

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Water Valve Sub x

File name: WASHMAC.DFS
Last modification: Sun Mar 12 15:01:35 1995
Date of printing: Sun Mar 12 15:05:29 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Oper	Un...	unplug washer	1		0.00	6.40	6.40	0.05	0.00	-	standard disassembly o...
2	Oper	Un...	pull away from wall	1		0.00	-	38.10	0.32	0.00	-	library disassembly oper...
3	Part	Un...	rear top cover scr...	2	Yes	6.30	10.00	26.30	0.22	0.00	-	screw unfasten & remove
4	Part	Un...	hot water hose	1		0.00	10.60	10.60	0.09	0.00	-	screw unfasten & remove
5	Part	Un...	cold water hose	1		0.00	10.60	10.60	0.09	0.00	-	screw unfasten & remove
6	Part	Un...	inlet seals	2	Yes	6.30	5.20	16.70	0.14	0.00	-	snap fit unfasten & remo...
7	Oper	Un...	unsnap to cover s...	1	Yes	0.00	3.20	3.20	0.03	0.00	-	standard disassembly o...
8	Oper	Un...	reorient to covers...	1	Yes	0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
9	Oper	Un...	snap lead vire w.v.	4	Yes	0.00	2.50	10.00	0.08	0.00	-	standard disassembly o...
10	Part	Un...	water valve screws	6	Yes	6.30	9.40	62.70	0.52	0.00	-	screw unfasten & remove
11	Sub	Srvc	water valve sub	1	Yes	0.00	5.00	5.00	0.04	0.00	9.70	remove

Figure B.49: Disassembly Worksheet - Water Valve

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Water Valve Sub x

File name: WASHMAC.DFS
Last modification: Sun Mar 12 15:01:35 1995
Date of printing: Sun Mar 12 15:05:29 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Sub	Srvc	water valve sub	1	Yes	0.00	2.60	4.90	7.50	0.06	0.00	9.70
2	Part	Re...	water valve screws	6	Yes	6.30	1.40	13.80	97.50	0.81	0.00	-
3	Oper	Re...	snap lead wire -w.v.	4	Yes	0.00	-	3.10	12.40	0.10	0.00	-
4	Oper	Re...	reorient tc covers...	1	Yes	0.00	-	4.50	4.50	0.04	0.00	-
5	Oper	Re...	snap tc cover sub	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
6	Part	Re...	inlet seals	2	Yes	0.00	2.00	2.20	8.40	0.07	0.00	-
7	Part	Re...	cold water hose	1		0.00	2.60	13.80	16.40	0.14	0.00	-
8	Part	Re...	hot water hose	1		0.00	2.60	13.80	16.40	0.14	0.00	-
9	Part	Re...	rear top cover scr...	2	Yes	6.30	2.00	13.80	37.90	0.32	0.00	-
10	Oper	Re...	Push against wall	1		0.00	-	-	28.10	0.23	0.00	-
11	Oper	Re...	Push fit refasten	1		0.00	-	4.40	4.40	0.04	0.00	-

Figure B.50: Reassembly Worksheet - Water Valve

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Power Cord

File name: WASHMAC.DFS
Last modification: Sun Mar 12 15:04:16 1995
Date of printing: Sun Mar 12 15:05:29 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Oper	Un...	Pull away from wall	1		0.00	-	38.10	0.32	0.00	-	library disassembly oper...
2	Oper	Un...	Unplug from wall	1		0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
3	Part	Un...	rear top cover scr...	2	Yes	4.20	9.40	23.00	0.19	0.00	-	screw unfasten & remove
4	Part	Un...	pc earth screw	1	Yes	4.20	9.40	13.60	0.11	0.00	-	screw unfasten & remove
5	Part	Un...	hot water hose	1		0.00	10.60	10.60	0.09	0.00	-	screw unfasten & remove
6	Part	Un...	cold water hose	1		0.00	10.60	10.60	0.09	0.00	-	screw unfasten & remove
7	Part	Dscd	screw covers	2	Yes	4.20	4.60	13.40	0.11	0.00	0.10	snap fit unfasten & remo...
8	Part	Un...	control panel scr...	2	Yes	4.20	9.40	23.00	0.19	0.00	-	screw unfasten & remove
9	Oper	Un...	Unsnap control p...	1	Yes	0.00	1.80	1.80	0.01	0.00	-	standard disassembly o...
10	Oper	Un...	reorient panel	1	Yes	0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
11	Oper	Un...	unsnap pcb conn...	12	Yes	0.00	2.50	30.00	0.25	0.00	-	standard disassembly o...
12	Sub	Un...	control panel sub	1	Yes	0.00	6.00	6.00	0.05	0.00	-	remove
13	Part	Un...	Front top coversc...	2	Yes	4.20	9.40	23.00	0.19	0.00	-	screw unfasten & remove
14	Oper	Un...	Reorient top cover	1		0.00	-	19.80	0.16	0.00	-	library disassembly oper...
15	Oper	Un...	unsnap power co...	2	Yes	0.00	2.50	5.00	0.04	0.00	-	standard disassembly o...
16	Oper	Un...	Unsnap harness	1	Yes	4.20	3.20	7.40	0.06	0.00	-	standard disassembly o...
17	Sub	Srvc	power cord	1	Yes	0.00	4.80	4.80	0.04	0.00	16.00	remove

Figure B.51: Disassembly Worksheet - Power Cord

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Power Cord

File name: WASHMAC.DFS
Last modification: Sun Mar 12 15:04:16 1995
Date of printing: Sun Mar 12 15:05:29 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Sub	Srvc	power cord	1	Yes	0.00	3.40	15.60	19.00	0.16	0.00	16.00
2	Oper	Re...	snap harness	1	Yes	0.00	-	2.90	2.90	0.02	0.00	-
3	Oper	Re...	snap power conn...	2	Yes	0.00	-	3.10	6.20	0.05	0.00	-
4	Oper	Re...	Reorient top cover	1		0.00	-	-	23.56	0.20	0.00	-
5	Part	Re...	Front top coversc...	2	Yes	4.20	1.40	13.80	34.60	0.29	0.00	-
6	Sub	Re...	control panel sub	1	Yes	0.00	4.60	3.80	8.40	0.07	0.00	-
7	Oper	Re...	snap pcb connect	12	Yes	0.00	-	3.10	37.20	0.31	0.00	-
8	Oper	Re...	reorient panel	1	Yes	0.00	-	4.50	4.50	0.04	0.00	-
9	Oper	Re...	Snap control panel	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
10	Part	Re...	control panel scr...	2	Yes	4.20	1.40	13.80	34.60	0.29	0.00	-
11	Part	New	screw covers	2	Yes	0.00	1.40	2.20	7.20	0.06	0.00	0.10
12	Part	Re...	cold water hose	1		0.00	2.60	13.80	16.40	0.14	0.00	-
13	Part	Re...	hot water hose	1		0.00	2.60	13.80	16.40	0.14	0.00	-
14	Part	Re...	pc earth screw	1	Yes	4.20	1.40	13.80	19.40	0.16	0.00	-
15	Part	Re...	rear top cover scr...	2	Yes	4.20	1.40	13.80	34.60	0.29	0.00	-
16	Oper	Re...	Push fit refasten	1		0.00	-	4.40	4.40	0.04	0.00	-
17	Oper	Re...	Push against wall	1		0.00	-	-	28.10	0.23	0.00	-

Figure B.52: Reassembly Worksheet - Power Cord

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Fuse x

File name: WASHMAC.DFS
Last modification: Sun Mar 12 15:03:31 1995
Date of printing: Sun Mar 12 15:05:29 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Oper	Un...	unplug washer	1		0.00	6.40	6.40	0.05	0.00	-	standard disassembly o...
2	Oper	Un...	Pull away from wall	1		0.00	-	38.10	0.32	0.00	-	library disassembly oper...
3	Part	Un...	rear top cover scr...	2	Yes	6.30	9.40	25.10	0.21	0.00	-	screw unfasten & remove
4	Part	Un...	hot water hose	1		0.00	10.60	10.60	0.09	0.00	-	screw unfasten & remove
5	Part	Un...	cold water hose	1		0.00	10.60	10.60	0.09	0.00	-	screw unfasten & remove
6	Part	Un...	inlet seals	2	Yes	6.30	4.60	15.50	0.13	0.00	-	snap fit unfasten & remo...
7	Oper	Un...	unsnap tc cover s...	1	Yes	0.00	3.20	3.20	0.03	0.00	-	standard disassembly o...
8	Oper	Un...	reorient tc covers...	1	Yes	0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
9	Oper	Un...	unfasten fuse hol...	1		0.00	3.60	3.60	0.03	0.00	-	standard disassembly o...
10	Part	Srvc	fuse	1		0.00	5.00	5.00	0.04	0.00	0.10	remove

Figure B.53: Disassembly Worksheet - Fuse

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Fuse x

File name: WASHMAC.DFS
Last modification: Sun Mar 12 15:03:31 1995
Date of printing: Sun Mar 12 15:05:29 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Part	Srvc	fuse	1		0.00	2.60	3.80	6.40	0.05	0.00	0.10
2	Oper	Re...	Snap fit refasten	1		0.00	-	2.20	2.20	0.02	0.00	-
3	Oper	Re...	reorient tc covers...	1	Yes	0.00	-	4.50	4.50	0.04	0.00	-
4	Oper	Re...	snap tc cover sub	1	Yes	0.00	-	2.20	2.20	0.02	0.00	-
5	Part	Re...	inlet seals	2	Yes	0.00	1.40	4.30	11.40	0.10	0.00	-
6	Part	Re...	cold water hose	1		0.00	2.60	13.80	16.40	0.14	0.00	-
7	Part	Re...	hot water hose	1		0.00	2.60	13.80	16.40	0.14	0.00	-
8	Part	Re...	rear top cover scr...	2	Yes	6.30	1.40	13.80	36.70	0.31	0.00	-
9	Oper	Re...	Push against wall	1		0.00	-	-	28.10	0.23	0.00	-
10	Oper	Re...	Plug in washer	1		0.00	-	4.40	4.40	0.04	0.00	-

Figure B.54: Reassembly Worksheet - Fuse

DESIGN FOR SERVICE DISASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Filter Net

File name: WASHMAC.DFS
Last modification: Tue Feb 07 11:45:41 1995
Date of printing: Sun Mar 12 15:05:29 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Remo... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Servi... Disca... Items $	Description
1	Oper	Un...	Open Lid	1		0.00	4.50	4.50	0.04	0.00	-	reorient & adjust
2	Part	Un...	Filter Net	1		0.00	5.00	5.00	0.04	0.00	-	snap fit unfasten & remo...
3	Oper	Un...	Clean Net	1		0.00	4.50	4.50	0.04	0.00	-	reorient & adjust

Figure B.55: Disassembly Worksheet - Filter Net

DESIGN FOR SERVICE REASSEMBLY WORKSHEET
Boothroyd Dewhurst, Inc.
Filter Net

File name: WASHMAC.DFS
Last modification: Tue Feb 07 11:45:41 1995
Date of printing: Sun Mar 12 15:05:29 1995

No.	Type	Cat.	Name	R... C...	From DFA	Tool Acq... sec	Item Acqui... sec	Inserti... or Op... sec	Total Time sec	Labor Cost $	Special Tools ... $	Serv... or N... Item...
1	Oper	Re...	Clean Net	1		0.00	-	4.50	4.50	0.04	0.00	-
2	Part	Re...	Filter Net	1		0.00	1.40	2.90	4.30	0.04	0.00	-
3	Oper	Re...	Close Lid	1		0.00	-	4.50	4.50	0.04	0.00	-

Figure B.56: Reassembly Worksheet - Filter Net

Drain Motor

Name	Cat.	Repeat Count	Tool Acquisition	Dis. Time	Modified Dis. Time	Item Set-aside	Total Time
Pull away from wall	Oper.	1	0.00	38.10	38.10	0.00	38.10
Unplug	Oper.	1	0.00	6.40	6.40	0.00	6.40
Flip onto side	Oper.	1	0.00	25.00	25.00	0.00	25.00
Shutter	Part	1	0.00	3.60	5.40	1.40	6.80
Unplug from Wire Harness	Oper.	1	0.00	2.50	3.75	0.00	3.75
Unhook Cable	Oper.	1	0.00	6.00	9.00	0.00	9.00
Drain Motor Screws	Part	4	4.20	20.00	30.00	1.40	129.80
Drain Motor Sub.	Sub.	1	0.00	4.40	6.60	1.40	8.00
					Disassembly Time =		226.85

Figure B.57: Disassembly Worksheet - Drain Motor

Name	Cat.	Repeat Count	Tool Acquisition	Re. Time	Modified Re. Time	Item Acquisition	Total Time
Drain Motor Sub.	Sub.	1	0.00	9.50	14.25	1.40	15.65
Drain Motor Screws	Part	4	4.20	23.70	35.55	1.40	152
Fasten Cable	Oper.	1	0.00	5.50	8.25	0.00	8.25
Snap Harness	Oper.	1	0.00	3.10	4.65	0.00	4.65
Shutter	Part	1	0.00	2.90	4.35	1.40	5.75
Flip upright	Oper.	1	0.00	15.00	15.00	0.00	15
Push against wall	Oper.	1	0.00	28.10	28.10	0.00	28.1
Plug in	Oper.	1	0.00	4.40	4.40	0.00	4.4
					Reassembly Time =		233.8

Figure B.58: Reassembly Worksheet - Drain Motor

Motor Subassembly

Name	Cat.	Repeat Count	Tool Acquisition	Dis. Time	Modified Dis. Time	Item Set-aside	Total Time
Pull away from wall	Oper.	1	0.00	38.10	38.10	0.00	38.10
Unplug	Oper.	1	0.00	6.40	6.40	0.00	6.40
Flip onto side	Oper.	1	0.00	25.00	25.00	0.00	25.00
Shutter	Part	1	0.00	3.60	5.40	2.60	8.00
Cut tie wrap	Oper.	2	6.30	2.00	3.00	0.00	12.30
Unfeed tie wrap	Part	2	0.00	2.40	3.60	2.00	11.20
Unfasten motor wires	Oper.	3	0.00	1.80	2.70	0.00	8.10
Loosen motor bolts	Oper.	2	6.30	11.30	16.95	0.00	40.20
Slide Motor sub	Oper.	1	0.00	5.00	7.50	0.00	7.50
Belt	Part	1	0.00	3.40	5.10	4.60	9.70
Motor bolts	Part	2	6.30	11.30	16.95	2.00	44.20
Plastic washers	Part	2	0.00	3.40	5.10	2.00	14.20
Motor sub	Part	1	0.00	3.40	5.10	4.60	9.70
Motor cushion	Part	2	0.00	3.40	5.10	2.00	14.20
					Disassembly Time =		248.8

Figure B.59: Disassembly Worksheet - Motor Subassembly

Name	Cat.	Repeat Count	Tool Acquisition	Re. Time	Modified Re. Time	Item Acquisition	Total Time
Motor cushion	Part	2	0.00	30.10	45.15	2.00	94.3
Motor sub	Part	1	0.00	44.50	66.75	4.60	71.35
Plastic washers	Part	2	0.00	21.90	32.85	2.00	69.70
Motor bolts	Part	2	6.30	19.40	29.10	2.00	68.50
Belt	Part	1	0.00	4.90	7.35	4.60	11.95
Slide Motor sub	Oper.	1	0.00	7.30	10.95	0.00	10.95
Tighten motor bolts	Oper.	2	6.30	11.20	16.80	0.00	39.90
Fasten motor wires	Oper.	3	0.00	2.20	3.30	0.00	9.90
Feed tie wrap	Part	2	0.00	4.90	7.35	2.00	18.70
Fasten tie wrap	Oper.	2	6.30	7.30	10.95	0.00	28.20
Shutter	Part	1	0.00	2.90	4.35	2.60	6.95
Flip upright	Oper.	1	0.00	15.00	15.00	0.00	15
Push against wall	Oper.	1	0.00	28.10	28.10	0.00	28.1
Plug in	Oper.	1	0.00	4.40	4.40	0.00	4.4
					Reassembly Time =		477.9

Figure B.60: Reassembly Worksheet - Motor Subassembly

Shaft Replacement

Name	Cat.	Repeat Count	Tool Acquisition	Dis. Time	Modified Dis. Time	Item Set-aside	Total Time
Pull away from wall	Oper.	1	0.00	38.10	38.10	0.00	38.10
Unplug	Oper.	1	0.00	6.40	6.40	0.00	6.40
Rear top cover screws	Part	2	6.30	8.00	8.00	1.40	25.10
Open lid	Oper.	1	0.00	2.00	2.00	0.00	2.00
Screw Covers	Part	2	6.30	5.20	5.20	1.40	19.50
Control Panel Screws	Part	2	6.30	11.30	11.30	1.40	31.70
Snap Fit Unfasten CP	Oper.	1	0.00	1.80	1.80	0.00	1.80
Reorient panel	Oper.	1	0.00	4.50	4.50	0.00	4.50
Front top cover screw	Part	2	6.30	8.00	8.00	1.40	25.10
Reorient Top Cover	Part	1	0.00	19.80	19.80	0.00	19.80
Tub Cover Screw	Part	4	6.30	8.00	8.00	1.40	43.90
Tub Cover	Part	1	0.00	10.80	10.80	4.60	15.40
Pulsator Cap	Part	1	6.30	3.20	3.20	2.60	12.10
Pulsator Bolt	Part	1	6.30	11.30	11.30	1.40	19.00
Pulsator Sub	Part	1	0.00	3.30	3.30	4.60	7.90
Spin Basket Bolts	Part	4	6.30	8.00	8.00	1.40	43.90
Spin Basket Sub	Part	1	0.00	1.40	1.40	4.60	6.00
Flip onto side	Oper.	1	0.00	25.00	25.00	0.00	25.00
Shutter	Part	1	0.00	3.60	5.40	2.60	8.00
Saddle Screws	Part	4	4.20	11.30	16.95	1.40	77.60
Saddle	Part	1	0.00	3.60	5.40	1.40	6.80
Cotter Pin	Part	1	0.00	5.00	7.50	1.40	8.90
Loosen motor bolts	Oper.	2	4.20	11.30	16.95	0.00	38.10
Slide Motor sub	Oper.	1	0.00	5.00	7.50	0.00	7.50
Belt	Part	1	0.00	7.00	10.50	1.40	11.90
Shaft Bolts	Part	4	4.20	11.30	16.95	1.40	77.60
Shaft Assembly	Part	1	0.00	10.90	16.35	4.60	20.95
					Disassembly Time =		604.55

Figure B.61: Disassembly Worksheet - Shaft Replacement

Name	Cat.	Repeat Count	Tool Acquisition	Re. Time	Modified Re. Time	Item Acquisition	Total Time
Shaft Assembly	Part	1	0.00	37.30	55.95	4.60	60.55
Shaft Bolts	Part	4	4.20	19.40	29.10	1.40	126.20
Belt	Part	1	0.00	7.40	11.10	1.40	12.50
Slide Motor sub	Oper.	1	0.00	7.30	10.95	0.00	10.95
Tighten Motor Bolts	Oper.	2	4.20	11.20	16.80	0.00	37.80
Cotter Pin	Part	1	0.00	11.00	16.50	1.40	17.90
Saddle	Part	1	0.00	7.00	10.50	1.40	11.90
Saddle Screws	Part	4	4.20	19.40	29.10	1.40	126.20
Shutter	Part	1	0.00	2.90	4.35	2.60	6.95
Flip onto side	Oper.	1	0.00	15.00	15.00	0.00	15.00
Spin Basket Sub	Part	1	0.00	15.70	15.70	4.60	20.30
Spin Basket Bolts	Part	4	6.30	13.80	13.80	1.40	67.10
Pulsator Sub	Part	1	0.00	4.90	4.90	4.60	9.50
Pulsator Bolt	Part	1	6.30	19.40	19.40	1.40	27.10
Pulsator Cap	Part	1	0.00	4.30	4.30	2.60	6.90
Tub Cover	Part	1	0.00	36.00	36.00	4.60	40.60
Tub Cover Screw	Part	4	6.30	13.80	13.80	1.40	67.10
Reorient Top Cover	Part	1	0.00	23.65	23.65	0.00	23.65
Front top cover screw	Part	2	6.30	13.80	13.80	1.40	36.70
Reorient panel	Oper.	1	0.00	4.50	4.50	0.00	4.50
Snap Fit Unfasten CP	Oper.	1	0.00	2.20	2.20	0.00	2.20
Control Panel Screws	Part	2	6.30	13.80	13.80	1.40	36.70
Screw Covers	Part	2	0.00	2.20	2.20	1.40	7.20
Open lid	Oper.	1	0.00	2.00	2.00	0.00	2.00
Rear top cover screws	Part	2	6.30	13.80	13.80	1.40	36.70
Push against wall	Oper.	1	0.00	28.10	28.10	0.00	28.1
Plug in	Oper.	1	0.00	4.40	4.40	0.00	4.4
					Reassembly Time =		846.70

Figure B.62: Reassembly Worksheet - Shaft Replacement

Drain Valve Bellows

Name	Cat.	Repeat Count	Tool Acquisition	Dis. Time	Modified Dis. Time	Item Set-aside	Total Time
Pull away from wall	Oper.	1	0.00	38.10	38.10	0.00	38.10
Unplug	Oper.	1	0.00	6.40	6.40	0.00	6.40
Flip onto side	Oper.	1	0.00	25.00	25.00	0.00	25.00
Shutter	Part	1	0.00	3.60	5.40	2.60	8.00
Unsnap Hose Clamp	Oper.	1	0.00	2.50	3.75	0.00	3.75
Unfasten drain hose	Oper.	1	0.00	5.00	7.50	0.00	7.50
Unhook Cable	Oper.	1	0.00	3.30	4.95	0.00	4.95
Cotter Pin	Part	1	0.00	3.60	5.40	1.40	6.80
DV Cover	Part	1	4.20	17.90	26.85	1.40	32.45
Deflect shaft lever	Oper.	1	0.00	5.00	7.50	0.00	7.50
DV Bellow Sub	Part	1	0.00	3.40	5.10	1.40	6.50
DV Bellow	Part	1	4.20	12.60	18.90	1.40	24.5
						Disassembly Time =	171.45

Figure B.63: Disassembly Worksheet - Drain Valve Bellows

Name	Cat.	Repeat Count	Tool Acquisition	Re. Time	Modified Re. Time	Item Acquisition	Total Time
Bellows	Part	1	4.20	8.60	12.90	1.40	18.5
DV Bellow Sub	Part	1	0.00	5.40	8.10	1.40	9.5
Deflect Shaft Lever	Oper.	1	0.00	5.00	7.50	0.00	7.5
DV Cover	Part	1	4.20	29.30	43.95	1.40	49.55
Cotter Pin	Part	1	0.00	11.00	16.50	1.40	17.9
Fasten Cable	Oper.	1	0.00	4.2	6.30	0.00	6.3
Connect Drain Hose	Oper.	1	0.00	6.20	9.30	0.00	9.3
Snap Hose Clamp	Part	1	0.00	3.10	4.65	1.40	6.05
Shutter	Part	1	0.00	2.90	4.35	2.60	6.95
Flip upright	Oper.	1	0.00	15.00	15.00	0.00	15
Push against wall	Oper.	1	0.00	28.10	28.10	0.00	28.1
Plug in	Oper.	1	0.00	4.40	4.40	0.00	4.4
						Reassembly Time =	179.05

Figure B.64: Reassembly Worksheet - Drain Valve Bellows

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